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Using Factors of Socioeconomic Status, Family Support, and Academic Preparation to Explain the Black-White Gap in Mathematics Achievement and Participation

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USING FACTORS OF SOCIOECONOMIC STATUS, FAMILY
SUPPORT, AND ACADEMIC PREPARATION TO EXPLAIN
THE BLACK-WHITE GAP IN MATHEMATICS
ACHIEVEMENT AND PARTICIPATION

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Engineering and Science Education

by
Charity Noel Watson
May 2012

Accepted by:
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Dr. Geoff Potvin
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Abstract

The Black-White achievement and participation gap in mathematics is a major concern for educators in America. In order to understand why these gaps exist and have continued to exist over the years, it is important to identify some of the factors that may contribute to them. However, one of the limitations in identifying factors that influence the disparities in achievement and participation between Black and White students is the issue of finding comparable and representative groups.

This study aspired to move beyond randomized experimental designs to studying a larger representative sample of Black college students who are equivalent to White college students on a number of factors hypothesized to impact achievement and participation in mathematics. Covariates dealing with socioeconomic status, family support, and academic preparation were considered in an attempt to understand the collective and isolated effects of external factors on the performance and representation disparities between Black and White college students. College calculus performance was chosen as an outcome of interest due to its role as a gatekeeper for STEM majors and careers. The likelihood of choosing a career in a STEM field was chosen as the other outcome of interest.

Results indicated that although Black students are performing significantly worse than White students in college calculus, after comparing Black students to White students with similar backgrounds, the gap between the two groups decreased

to a statistically non-significant difference. Also, it was found that after comparing similar groups of Black and White students, Black students were more likely to report choosing a career in a STEM field.

Dedication

“It’s much bigger issues in the world, I know. But, I first had to take care of the world I know.”—Shawn Corey Carter

This dissertation is dedicated to the three teachers, all who happen to be Black women, who played a pivotal role in shaping my education and life. First, Joyce Jordan Smith, my preschool teacher who first instilled the importance of education and the thirst for knowledge in me. Second, Angela Hill, my high school chemistry teacher who constantly encouraged me and fostered a sense of self-awareness of my true potential. Finally, Sarah Ford, my high school calculus teacher who helped me fall in love with the subject of mathematics and always pushed me beyond what I thought I was capable of.

Acknowledgments

Giving all honor and glory to my Lord and Saviour Jesus Christ, whom without none of this would be possible.

I am grateful to my committee, Dr. Zahra Hazari, Dr. Geoff Potvin, Dr. Melanie Cooper, and Dr. Bill Moss, for the giving of your advice and time during this process. I am immensely thankful to Dr. Zahra Hazari, my advisor and chair of my dissertation committee, for your endless amount of guidance, support, and encouragement throughout this entire process. This experience has been so rewarding and beneficial for me, and I could not have been more fortunate than to have you serve as a mentor and ally through it all. I am also appreciative of Dr. Geoff Potvin for sharing your wealth of knowledge on education research and for always being willing to play the role of “tech support”.

I also want to thank the National Science Foundation for funding both the FIC-SMath and PRiSE projects which were used in this work and Dr. Philip Sadler and Dr. Gerhard Sonnert at the Science Education Department at Harvard-Smithsonian Center for Astrophysics for allowing me to be a part of these wonderful projects.

Finally, I am deeply and forever grateful to my family and friends who stood by me throughout this time. Your unwavering support and encouragement were the driving force behind my motivation to keep going, especially at those moments when I did not want to. A very special thank you goes to my extraordinary and loving

parents. You have always been my biggest champions and I am so blessed to have the two of you in my corner. I hope that I can continue to make you proud.

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Chapter 1

Introduction

1.1 Blacks in America

In the 1954 landmark *Brown v. Board of Education* case, the United States Supreme Court made the monumental decision that laws upholding separate public schools for White and Black students were unconstitutional. Now, fifty-eight years later, when segregation is no longer the accepted norm and in theory, all children, regardless of race or ethnicity, should have equal opportunities for upward mobility, there still exist large differences in the lives of Black and White citizens. There are racial and economic inequalities which work to create differing experiences in the lives and, specifically, educational opportunities available to Black and White children at an early age. For example, the average Black child spends nearly six years in poverty, in contrast to less than one year for the average white child [Magnuson and Waldfogel, 2008]. As a result, Black and White children are afforded differing opportunities which hold consequences for their future success.

Most Americans subscribe to the ideology of a meritocratic society – a society in which a person’s social and occupational status is gained through achievements

as opposed to ascription. It was a commitment to meritocracy which influenced the establishment of the American public school system, which was in part designed to foster social equality through equal access to education [Hallinan, 2001]. As a major societal institution, education is commonly viewed as providing access to various resources in society. In this sense, education can also be viewed as a means to reduce social disparities and counter present inequalities. President Barack Obama took a similar stance in his 2009 address at the NAACP Centennial Convention during which he stated, “...there is no stronger weapon against inequality and no better path to opportunity than an education that can unlock a child’s God-given potential.”

It is noted that throughout this work, the term “Black” will be used to refer to those who identified themselves as racially Black (non-Hispanic or multi-racial). This classification includes African-Americans, Caribbean-Americans, etc. The use of the term “African American” will be used only when citing other work and research which classify the subjects in the studies as such.

1.2 Black-White Achievement Gap

A more specific focus for the nation has been the persistent Black-White gap in the achievement of students. The National Assessment of Educational Progress (NAEP) releases an annual report card for the nation’s level of achievement across disciplines and grade levels. Attention is generally placed on whether the scores of students are falling or rising and if the disparities in achievement are shifting. This is in part done in order to assess if efforts such as the *No Child Left Behind Act* and others like it are succeeding or failing and where policy emphasis should be shifted.

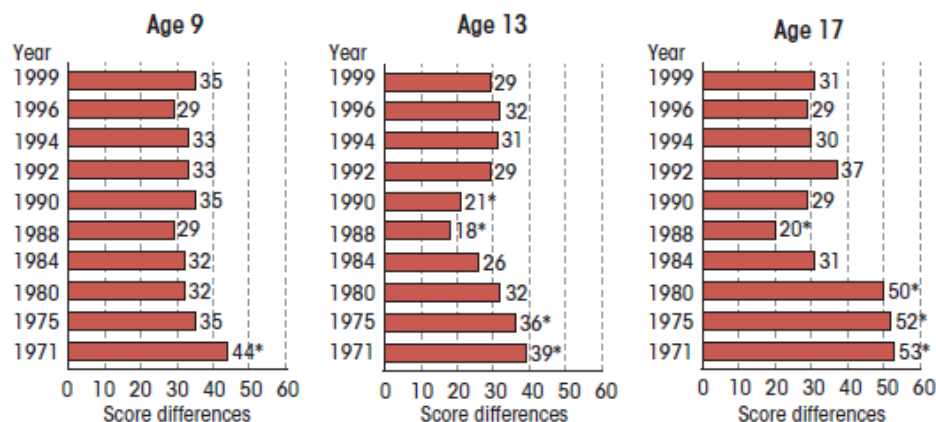
The nation’s endeavors to address the gaps in education has quite a long history. Expectations grew with desegregation in schools and even with the *Elementary*

and Secondary Education Act in the 1960s which emphasized equal access to education and opportunities. Changes such as these caused people to grow more optimistic about progress in education and in society as a whole.

Of the several disparities present between Black and White Americans, a prominent and concerning one remains the disparity in their outcomes in schools. In general, Black children enter school performing worse on measures of school readiness when compared to White children and also score lower during schooling years on tests of reading and math achievement [Magnuson and Waldfogel, 2008]. These differences, commonly referred to as the “achievement gap”, have gained an increasing degree of attention over the years. One can certainly take the position that, relative to the days of segregation, Blacks have made meaningful gains in academic performance. However, the substantial gaps that still remain serve as a convincing indication that Blacks in America are still lagging far behind.

Although Black-White achievement gaps have persisted, their magnitude has changed over the period since NAEP began its assessments in the 1970s. A majority of the progress in closing the achievement gap in reading and mathematics occurred during the 1970s and 1980s. After that, however, the overall progress in closing the gaps has slowed [Barton and Coley, 2010]. For instance, as Figure 1.1 shows, the reading score gaps between Whites and Blacks decreased from 1971 to 1999, at all grade levels. However, for 4th-, 8th-, and 12th-graders, the reading score gap in 1988 was smaller than that in 1999. Also, while gaps in the mathematics scores between White and Black 9-, 13- and 17- year-olds have narrowed significantly since 1973, the gaps remained stable between 1992 and 1999, which is illustrated in Figure 1.2.

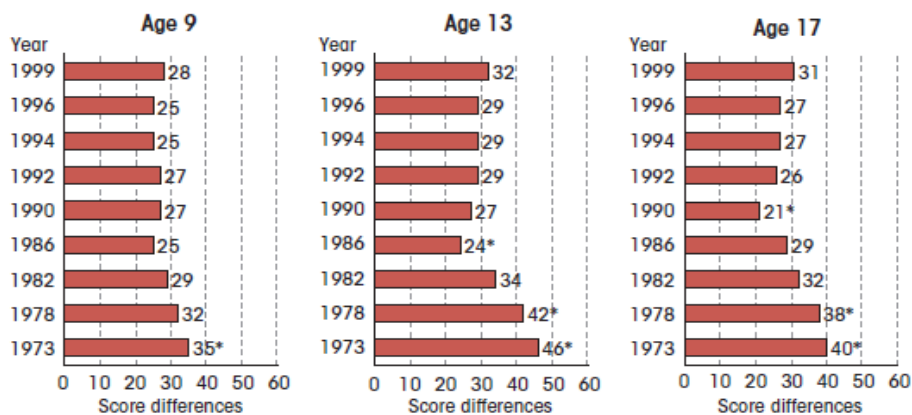
Figure 1.1: Differences between White and Black students' average NAEP reading scale scores, by age: 1973-1999



* Statistically significantly different from 1999.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), NAEP 1999, *Trends in Academic Progress: Three Decades of Student Performance*, based on 1999 Long-Term Trend Assessment.

Figure 1.2: Differences between White and Black students' average NAEP mathematics scale scores, by age: 1973-1999



* Statistically significantly different from 1999.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), NAEP 1999, *Trends in Academic Progress: Three Decades of Student Performance*, based on 1999 Long-Term Trend Assessment.

1.3 Blacks in Mathematics

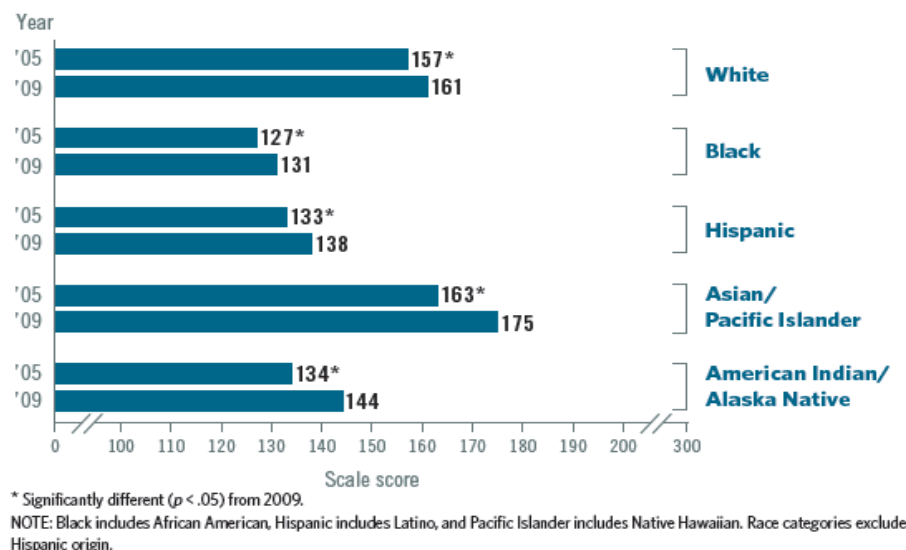
A few decades ago, researchers began to focus more attention on the status of Blacks in mathematics. Through this research they found a trend of low mathematics participation and achievement. Black students were enrolling in secondary mathematics courses at low rates and were under-performing on achievement tests when compared to other groups. Data also indicated that they enrolled in fewer mathematics courses during high school than Whites. The data suggested that disproportionate numbers of Black students were being blocked from admission in mathematics courses at the college level considering that a student who had taken less than four semesters of mathematics in the last two years of high school is not likely to be prepared for these courses [Johnson, 1984].

Differences in mathematics achievement between Blacks and Whites have become more prominent issues as standardized assessment has increasingly become a part of the state and federal education policies for school improvement. A number of educational reform initiatives have been emphasized in mathematics education in an attempt to narrow the achievement gap and improve mathematical proficiency overall. However, the differences between Black and White students in mathematics achievement remain a major concern. Data by race given by NAEP show that the disparities in mathematics scores between fourth and eighth grade Black and White students narrowed in the 1970s and 1980s, but then grew in the 1980s and 1990s [Lee et al., 2007].

Data from NAEP also show that although mathematics scores for twelfth grade students have increased over the years, Black students still lag behind their peers. For instance, as illustrated in Figure 1.3, between the years 2005 and 2009 Black students' average score increased by four points. However, these Black students were

still outperformed by other racial groups, including other underrepresented minority groups such as Hispanics and American Indians/Alaskan Natives.

Figure 1.3: *Average scale scores in 12th grade NAEP Mathematics, by race/ethnicity: 2005 and 2009*

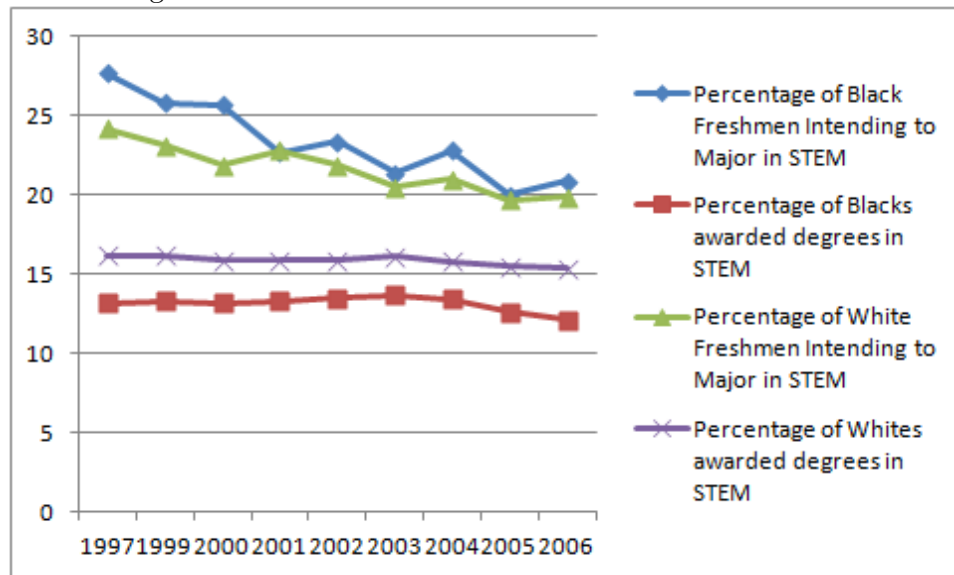


1.4 Blacks in STEM

At the university level, Blacks are underrepresented among college graduates in mathematics, science, and engineering, even though they express a strong interest in these majors when they enter college [Moreno and Muller, 1999]. In 2006, 21% of Black freshmen intended to major in science, technology, engineering, and mathematics (STEM) fields, according to data from Science and Engineering Indicators 2008. Interestingly, that number is larger than the percentage of incoming white freshmen, 19%, who planned to major in science or engineering. Given the abundance of evidence of underrepresentation and underperformance of Black students in STEM fields, these data are reassuring, while also surprising. But, this trend is not

neccessarily new. Data dating back to 1985 show Black freshmen consistently choosing STEM majors at a higher rate than White freshmen. Also, Black students enroll in college at rates roughly on par with their representation in the population, so at the very beginning of college, the representation of Blacks in STEM fields is slightly in excess of their representation in the general population [Sasso, 2008]. Figure 1.4 shows that Black freshman are continually intending STEM majors at a higher rate than White freshmen. However, the attrition rates from both a STEM major, and from college itself, are greater for Blacks than they are for the average college student, also illustrated in Figure 1.4. This results in Blacks being underrepresented among those with bachelor's degrees in STEM fields and even less well represented at every subsequent phase of the career path despite their initial desire to pursue such career paths.

Figure 1.4: *Percentages of Blacks/Whites intending to major in STEM and Blacks/Whites awarded STEM degrees: 1997-2006*



1.5 Importance of Calculus

Calculus at the college level is often viewed as a gatekeeper for many higher-level STEM courses. As a result, college calculus also plays this role for many careers including mathematics, sciences, engineering, medicine, and even some areas of business. It has been argued that calculus provides a foundation for understanding higher-level STEM courses and it is often a formal prerequisite for enrolling in these courses. Successful completion of calculus is considered a requirement for success in most STEM majors [Gainen and Willemson, 1995]. While subjects such as physics, astronomy, engineering, and of course, mathematics make particularly ample use of calculus, other disciplines such as biology, chemistry, and economics, also make use of its applications and concepts.

Whereas success in college calculus opens the door to many STEM career paths, the failure in college calculus bars these opportunities for students. Calculus is generally seen as a difficult course and is thus perceived as a hurdle for many students. However, there is little evidence to show that calculus is a hurdle in the same way for all students [Moreno and Muller, 1999]. No one would argue against a strong background in high school mathematics courses being an advantage in college calculus, but it is not well known what other factors help influence performance in these courses. In addition, although Black Americans earn lower overall grade point averages than White American college students, there is little specific information about their performance in freshmen calculus or other quantitative courses [Erekson, 1992, Jay and D’Augelli, 1991, Nettles et al., 1986].

1.6 Contributing Factors

Several factors have been cited to explain the underrepresentation of Black scientists and mathematicians but there have been few attempts to present a model for black students' college major or career choice. Black college students are over-represented in those occupations which tend to generate lower incomes [Magnuson and Waldfogel, 2008]. There is a far-reaching belief in our society that math and science subjects are quite difficult [Powell, 1990]. Even though this belief may actually function on the unconscious level, it has been integrated into the thought processes of both Blacks and Whites in America. It is another widely held belief that people of low intellect are not expected to pursue careers in math or science. As a result, becoming a scientist or mathematician is seen as contradictory to the capabilities of Blacks in America.

As stated earlier, the economic circumstances in which Black and White children are raised differ considerably. So, understanding the role of inequality is important because the recent growth in economic inequality has disproportionately affected Black Americans, who were more likely than White Americans to be at lower levels of the earnings, income, and wealth distribution to start with [Magnuson and Waldfogel, 2008]. Thus, to the extent that growing economic inequality has social and educational consequences, these are likely to be more apparent for Black Americans than for White Americans.

About five decades ago many people adopted the liberal idea of the racial achievement gap being a product of some combination of poverty, racial segregation, and insufficient funding of Black schools [Jencks and Phillips, 1998]. However, since then, the number of affluent Black families have grown, yet their children's academic performance still lags behind that of White children from equally affluent homes.

More recent studies have found that using students' socioeconomic status (SES) solely as an explanatory factor for the Black-White mathematics achievement gap is not sufficient [Lubienski, 2002]. This was evidenced by low-SES white students scoring equal to or higher than high-SES black students on the math portion of the *National Assessment of Educational Progress* in both 1990 and 1996.

Missing from the literature are sufficient studies pertaining to mathematics achievement within the Black population. For example, there are very few studies that address whether Black students process analytical information differently, or whether they possess certain characteristics that affect learning and attitudes towards mathematics. Some important information has been identified, such as the need for positive role models in mathematics and the absence of such significant others in the lives of many Black students [Anderson, 1990]. In general, significant amount of variance in mathematics achievement has been accounted for by mathematics anxiety, ability, test anxiety, and teacher comments [Green, 1990]. The effects within the Black population specifically, however, have not been examined. In order to optimize the effect of interventions designed to improve mathematics achievement among Black students, more information is needed to possibly identify characteristics that may affect these variables.

1.7 Equity/Equality

Many years ago it was a widely held belief that differences in intelligence and cognitive ability were a product of biological or genetic mechanisms. In the modern era, however, it is mostly understood that differences in intelligence, especially across population groups, are due primarily to differing environments. Given that there is evidence suggesting that external environmental conditions aid in explaining the

disparities between Blacks' and Whites' achievement [White, 1982, Grootenboer and Hemmings, 2007], it is even more pressing that we attempt to understand the direct causes of the Black-White achievement gap so that we may begin to meaningfully and sustainably affect change. A lack of such efforts will certainly result in little being done to change the playing field in favor of Black students' success, as evidenced by years of stagnation rather than true reform and positive change. Focusing on these issues is not only a matter of equity and equality, but also of increasing national capacity. One of the greatest resources of a country is a highly skilled workforce [Magnuson and Waldfogel, 2008]. Therefore, in an economic system based on intense competition among individuals, such as in the US, there is good reason to demand changes in educational practice that will rapidly diminish and soon eliminate this achievement gap for the good of all [Norman et al., 2001]. The continued homogeneity of many STEM fields with respect to race is disconcerting, particularly in light of society's increasing emphasis on technological competence and scientific ability. Greater diversity in these fields means greater variation in perspectives and approaches, therefore leading to increased innovation and ingenuity to drive economic growth.

In summary, it is clear that there exists a problem with respect to the mathematical achievement of Blacks in this nation. An array of reports and studies have surfaced which indicate that Blacks are receiving low scores on mathematics tests and under-performing in mathematics courses. Given the growing technological nature of our society, this weakness in the area of mathematics among the Black population decreases their ability to compete for certain jobs or pursue those careers which require prerequisites in mathematics, even if they have the desire to do so. In general, Blacks are disadvantaged when competing in the workplace or gaining advanced training. In order to effectively meet the academic needs of these students, it is not enough to

simply contrast the performance of Black students and White students and simply speculate on the causes, as many have done in the past. Instead we need to sharpen our lens to focus on factors that may be affecting the achievement of Blacks in mathematics in order to make reforms that are based on evidence and thus, are more likely to affect change.

Chapter 2

Literature Review

This chapter will highlight relevant literature and research that have focused on topics related to the focus of this study. First, it will begin with a brief overview of the mathematics education literature that has success of Black students in mathematics as the focal point. Then it goes on to discuss attention paid to Black Americans and other under-represented minorities in college calculus and the underrepresentation of minorities in STEM fields. Next, the influence of key factors are introduced, namely socioeconomic status, family support, and academic preparation and their effect on mathematics achievement and participation is explained. Additionally, this chapter will point out the various limitations of other work done pertaining to the Black-White mathematics achievement gap and will go on to explain the purpose of this particular study and its attempt to address the underlying issues of the achievement and participation gap while paying close attention to the dissimilarities of the two groups. Finally, this chapter will present the guiding rationale for the study presented in this work.

2.1 Introduction

The problem of disparities in mathematics achievement and participation between Black and White students in America is a major concern for educators. In order to understand why this gap exists and has continued to exist over the years, it is important to attempt to identify some of the factors that may contribute to it. However, it is also of importance to find an appropriate way to frame the problem. This will serve to not only provide us with a better understanding of the problem, but will also impact the way we address the problem and make efforts to solve it [Flores, 2007]. While it is valuable to be able to recognize a problem, such as achievement gaps, it is of greater value to be able to understand and address the latent causes of such problems. Transforming the way in which the disparity in mathematics performance and representation between Blacks and Whites is framed as a problem has the potential to lead to productive investigation into understanding the key issues and how to address them [Flores, 2007].

2.2 Mathematics Education Literature

In studying factors that contribute to Black-American students' success in mathematics, researchers have taken two main approaches. One being a focus on effective individual teachers, and the other being a focus on broader reform projects. From research on teachers' practices, it was learned that Black-American students benefit from a culturally relevant pedagogy [Ladson-Billings, 1997]. Ladson-Billings clarifies that this pedagogy entails treating their students like they are competent; providing instructional support for them; extending students' thinking and ability beyond what they already know; focusing the classroom on instruction; and having

in-depth knowledge of their students [Ladson-Billings, 1997]. Other research further documents these practices by showing that successful math teachers of minority students encourage communication between students and teacher, have students work in cooperative groups, question content, provide open-ended problem solving connected to student realities, incorporate social action, and connect mathematics to students' cultural heritage [Gutierrez, 2000].

Research has also shown that minority and low-income students are less likely than other students to have teachers who emphasize high quality mathematics instruction or utilize the appropriate use of resources [Flores, 2007]. For example, African American and Latino students are less likely than White students to have access to teachers who emphasize reasoning and non-routine problem solving and teachers who use computers for simulations and applications. Often, students whose demographic background differs from that of their teachers are put in situations where the teacher assumes deficits in the students, rather than locating and teaching to their strengths, such as resilience, eagerness, energy, and creativity. Teachers may attribute the failure of a student to thrive intellectually as a deficit in the student rather than a deficit in their own teaching. As a consequence, teachers may be teaching less when they should be teaching more. Different expectations for different students are often reflected in the ways teachers teach and test [Flores, 2007].

2.3 Minorities in College Calculus

Although a number of critical elements for teaching mathematics to minority students have been identified, it is less clear what some of the underlying causes for the low performance of Blacks in mathematics may be. Also, although it is well known that Black American students earn lower overall grade point averages than White

American college students, there is not an abundance of information about their performance in college calculus [Erekson, 1992, Nettles et al., 1986]. Since calculus at the university level is a prerequisite for most STEM courses, successful completion of the course is required for entry into a STEM major and, consequently, a STEM career.

In one particular study, an open-ended survey of college professors was conducted by Uri Triesman [1992] which sought to find out what could be done to alleviate the failure of minority students in calculus. One key finding of the survey was that there were four widely held beliefs about the causes of minority students' failure in college calculus. From the responses it was believed that the low performance of minority students in college calculus could be attributed to low motivation, poor academic preparation, lack of family support, and low income.

First, there was the belief that there is a motivation gap contributing to the performance gap. This argument presents the claim that it is not that minority students are unmotivated, but that they are not as motivated as other groups of students. The implication is that small differences in motivation could have large effects in highly competitive and difficult courses. The few A's given would go to the students who, because of their high level of motivation, were willing to work extraordinarily hard.

The second idea presented the view that the failure in calculus among minority students had more to do with achieved status than ascribed status. In other words, the under-performance had nothing to do with race or ethnicity, instead it was a result of income. It was conjectured that if you were to control for income, all the differences would disappear.

The third problem conjectured was a lack of family support or understanding of higher education. The idea was, roughly, that since the families of these students

often did not have rich educational backgrounds, how could they pass on to their kids the survival skills they would need in college? Moreover, some faculty members thought that the parents did not push their kids hard enough.

The fourth belief pointed toward inadequate academic preparation as the culprit. It was thought that underrepresented minority students often enter college with fewer credit hours of science and mathematics from high school and with substantially lower SAT scores. Thus, the fault lies not with the university itself but instead with what the students bring with them to the university, namely prior preparation. Taking the argument a step further, several faculty members noted the “vertical” organization of mathematics and science. New topics in mathematics and the sciences depend on topics which precede them; courses in mathematics and science depend on courses that precede them. This characteristic of mathematics and science makes it difficult for students to improve their performance once they are having difficulty.

Of course, this study does not provide empirical evidence of the effect these factors may have on performance in college calculus since it is based on beliefs and suppositions. However, it does present some issues which can be explored in an effort to lend to the understanding of the underlying causes of the Black-White achievement and participation gap. It should be noted that for the purposes of this study, the factors of interest relate to income, family background/support, and academic preparation. These are all considered to be external factors. Thus, working under the assumption that motivation is an internal factor, it was not a focus of the current study.

2.4 Socioeconomic Status as a Determining Factor

A number of sociologists who rejected biological determinism as the cause of racial performance gaps claimed that the characteristics of Black families accounted for racial disparities in educational outcomes. During the 1960s and 1970s, sociologists were actively studying processes for intergenerational mobility [Sewell et al., 1969, Sewell and Hauser, 1975, Blau and Duncan, 1967]. This research showed that family background was a critical factor in status attainment where the higher a father's educational and occupational status, the higher the son's socioeconomic status. The studies also determined that the influence of father's status on son's status remained fairly constant over the first half of the 20th century. This finding implied that society was not becoming more meritocratic, even during a period of dramatic expansion of schooling [Hallinan, 2001].

Income inequality among American families has grown steadily since the 1980s, as has the racial-ethnic income gap [Campbell et al., 2008]. This trend, documented in Table 2.1, was seen by the standard deviation of U.S. family income doubling from the 1980 to 2000 census, and the gaps between racial-ethnic groups rising during this period. Specifically, the family income gap between Blacks and Whites rose by more than 50% over these 20 years. Family income has been found to be a significant predictor of educational attainment, especially college attendance [Belley and Lochner, 2007]. Although estimates of the impact of family income on test scores vary depending on the data used and standardized test scores analyzed, the results consistently show a small but statistically significant effect [Phillips et al., 1998]. However, variation in parental education, income, and poverty status have been found by some studies to explain between 25 and 50% of the variation in the Black-White test score gap [Brooks-Gunn et al., 1996, Cook and Evans, 2000]. Research has also

shown that convergence in SES accounted for a large portion of the reduction of gaps observed in the 1980s [Hedges and Nowell, 1998]. More recent studies have concluded that the observed increases in income inequality in the U.S. have not contributed directly to the lack of progress in reducing racial-ethnic test score gaps. Even though income appears to influence test scores at the bottom of the income distribution, especially for Blacks, recent increases in income inequality are largely due to rapid income growth at the top [Campbell et al., 2008].

Table 2.1: *Family Income by Race/Ethnicity, 1970-2000*

| | Mean Family Income, Total Population | Standard Deviation, Family Income | Mean Family Income: Whites | Mean Family Income: Blacks | Income Difference: White -Black |
|------|---|--|----------------------------------|----------------------------------|--|
| 1970 | \$47,272 | 34,398 | \$50,780 | \$31,857 | \$18,923 |
| 1980 | \$45,361 | 31,659 | \$47,771 | \$32,567 | \$15,204 |
| 1990 | \$52,534 | 45,458 | \$55,841 | \$36,804 | \$19,037 |
| 2000 | \$59,015 | 60,589 | \$64,150 | \$40,628 | \$23,522 |

One particular study examined Black-White gaps in mathematics achievement using NAEP (National Assessment of Educational Progress) data from 1990 and 1996 and explored the extent to which such gaps could be attributable to SES differences between Black and White students [Lubienski, 2002]. The analysis of race and SES together revealed that the Black-White gaps were significant at the lowest and highest SES levels, with the gaps larger at the highest level. SES correlated more closely with achievement for White students than for Black students. The race-SES analyses also indicated that the lowest SES White students consistently scored equal to or higher (often significantly so) than the highest SES Black students across 4th, 8th, and 12th grades in both 1990 and 1996. This not only reveals a weakness in using SES as a sole explanatory factor for the Black-White achievement gap, but it also highlights the need to understand more about underlying causes of Black-White differences that go

beyond SES factors. It should also be noted that the SES variable used in this study was composed of two variables available in the NAEP data set - literacy resources in the home (e.g., books, encyclopedias, magazines, and newspapers) and parental education. So, the variable itself relied on students' self-reports of this information and thus becomes more reliable as grade level increases. This, combined with the exclusion of family income, presents a limitation of this SES variable. Since census data reveal there are different income distributions for Black and White populations [Bureau, 2010], SES group comparisons between Black and White students should take income into consideration. However, gathering such data from student self-report poses validity concerns since most students may not be able to accurately report their family income.

Literature on achievement has also shown that the education level of parents is important in predicting children's academic achievement [Haveman and Wolfe, 1995]. Research has indicated a positive relationship between education level of the parents and the student performance. Also, variables closely related to level of parental education such as income and occupation have been shown to have a positive association with a student's mathematics achievement [Xin and Kishor, 1997, Schreiber, 2002]. Considering privacy and validity issues in having subjects report on household income, parental education is often used as a proxy for income. Thus, multiple measures for SES should be used to compensate for the practical limitations of determining household income.

2.5 Family Support as a Determining Factor

There exists evidence showing that family encouragement along with family interest in schools and classrooms affect student's achievement, attitudes, and aspi-

rations [Epstein, 1987]. In fact, one of the contextual factors found to be uniquely relevant to the development of adolescents' career interests is parent support [Ferry et al., 2000, Lapan et al., 1999]. For example, research has shown that perceived support from fathers relates to the educational plans and career expectations of Mexican American high school girls [McWhiter et al., 1998]. Research also shows that parental encouragement has significant effects on self-efficacy, outcome expectations, and mathematics and science career interests among middle school students [Ferry et al., 2000]. There also exists research that suggests that the support and encouragement of mothers to explore careers related to mathematics, as well as their help in connecting mathematics and science courses to later career possibilities, is especially important to their future careers [Turner et al., 2004].

Throughout studies focused on family and achievement, variables categorized under family support include verbal encouragement and interactions regarding schoolwork, expectations of school performance, academic guidance, family's expectations of academic performance, and general support. During one study, it was found that the expectations that parents have of their children and their ability to establish and enforce firm structures and boundaries for the child in an environment of nurturing and support distinguished high achievers from low achievers [Clark, 1983]. In another study conducted with seventh graders, it was found that parental expectations contribute to mathematics and science achievement [Reynolds, 1991].

It has been shown that when families participate and support their children's education in positive ways, children can accomplish higher grades, perform better on exams, demonstrate more positive attitudes towards school, graduate at higher rates, and are even more likely to enroll in higher education [Becher, 1984, Henderson and Berla, 1994]. This support is also important for mathematics achievement. Parents can support their child's mathematics achievement by emphasizing the importance of

mathematics in careers and even by visiting science/mathematics related events and museums with their child [Smith and Hausafus, 1998]. It has also been found that families believing that mathematics is one of the most important subjects for their child and encouraging their child to take advanced mathematics courses, math test scores can be affected more than attending parent/teacher conferences or more than having books, magazines, or math video games in the home [Smith and Hausafus, 1998].

2.6 Academic Preparation as a Determining Factor

The mathematics content of elementary and middle schools is largely standardized within school systems. However, once a student reaches high school they are given more choices about the mathematics they choose to study. They can choose to accelerate their academic progress by preparing for algebra, or even take courses designed to strengthen and broaden their existing mathematical knowledge and skills [Stiff and Harvey, 1988].

According to recent data from NAEP, taking higher-level mathematics courses was generally associated with higher scores on the 2008 mathematics assessment at ages 13 and 17 [NAEP, 2008]. For example, 13-year-olds who were enrolled in algebra classes scored higher on average than those enrolled in pre-algebra or regular mathematics. Also, students of age 17 who had taken pre-calculus or calculus had a significantly higher average score than students who had taken second-year algebra or trigonometry. Students whose highest-level mathematics course was pre-algebra or general mathematics scored lower than students in the other course taking categories,

including first- or second-year algebra and geometry.

As mentioned earlier, it has been found that Black students generally enroll in fewer courses in mathematics than White students. For example, in 2005 the percentage of Black students taking trigonometry, pre-calculus, and calculus was 3.9%, 17.9%, and 5.5% respectively [NCES, 2007]. While the percentage of White students taking these courses in the same year was 9.6%, 32%, and 15.3% respectively. In addition, using data from the College Entrance Examination Board, it was found that Black American high school students take significantly fewer algebra and geometry courses than their White counterparts [Jones, 1984]. This was also of importance because the number of high school algebra and geometry courses taken by a student was a significant predictor of scores on standardized mathematics achievement tests [Jones, 1984]. So, it would seem logical that the poor achievement of Black American students is due partly to the lack of mathematics they study in high school.

The consequences of taking relatively few mathematics courses in high school can be severe. It has been reported that career choices in STEM are seriously limited without four years of secondary school mathematics, including two years of algebra, one of geometry, and an additional year of pre-calculus [Sells, 1980]. The NLS-72 even found a positive correlation between the number of semesters of mathematics completed in high school and the completion of the bachelor's degree on schedule [Commission, 1979].

It is generally argued that the number of advanced mathematics and science courses students take in high school is a factor influencing Black students' career considerations. It has been shown that both Black and White students with more mathematics courses taken in high school are more likely to choose a STEM major in college [Johnson, 1984, Thomas, 1984]. There exists a report on a survey of 3,000 college students which found that enrollment in advanced mathematics in high school

is one of the best predictors of whether or not a student would pursue a career in mathematics or science [Griffin, 1990]. Another study of 753 college students which found that the number of high school mathematics and science courses taken had significant direct effects on students' college field of study [Maple and Stage, 1991].

2.7 Limitations of Prior Research

In studying the causes for the Black-White achievement gaps, prior research has not been able to explain the Black-White gap through structural factors alone, although part of the gap has been accounted for by differences in socioeconomic status [Lubienski, 2002]. In other words, achievement gaps continue to be observed at various socioeconomic levels [Magnuson and Waldfogel, 2008]. Other research points to psychological factors, such as isolation and low social status, as additional contributing factors [Cohen et al., 2006, Cohen et al., 2009, Walton and Cohen, 2011]. Another psychological factor thought to contribute to this achievement gap is stereotype threat. The term “stereotype threat” refers to being at risk of confirming, as self-characteristic, a negative stereotype about one’s group [Steele and Aronson, 1995]. The term was first used by Steele and Aronson [1995] who showed in several experiments that Black college freshmen and sophomores performed more poorly on standardized tests than White students when their race was emphasized. When race was not emphasized, however, Black students performed better and equivalently with White students. The results showed that performance in academic contexts can be harmed by the awareness that one’s behavior might be viewed through the lens of racial stereotypes.

However, these types of psychological factors which are internal to the individual are a result of the individual experiencing external social and cultural marginal-

ization in both overt and subtle forms. Thus, it is critical to understand external inequalities that result in the increasing under-achievement for Black Americans as they move up the educational ladder if we are to lessen educational disadvantage on a broader scale. Also, it is necessary again to point out that no known study has been able to entirely explain the achievement gap between Black and White Americans. Also, no other known studies have compared the relative and compounded effects of different classifications of factors.

One of the limitations in identifying factors that influence the disparities in achievement between Black and White students is the issue of finding comparable and representative groups. Walton and Cohen [2011] point out this difficulty in their experiment, which randomly assigned European American and African American students from a university to control and treatment groups, but did not randomly sample these students from a representative population or ensure equivalence between the racial groups on certain covariates. We note that in this particular instance, random assignment does not ensure equivalence between the European and African American students because the two groups were not sampled from populations that are the same. So, the authors' comparisons were mainly restricted to within racial groups. For example, comparisons were made between the African Americans who received the treatment and African Americans who did not. However, because these students were not randomly sampled, the results cannot be generalized to the general population of African Americans. In addition, given that certain social marginalization is connected to racial identity, it would be highly beneficial to the understanding of race-based differences to study marginalized and non-marginalized racial groups that are comparable on external structural and social factors.

2.8 Purpose of Study

This study aims to move beyond a randomized experimental design to studying a larger representative sample of Black college students who are equivalent to White college students on a number of factors previously found to impact achievement and participation in mathematics. Covariates dealing with SES, family background, and academic preparation are considered in an attempt to understand the collective and isolated effects of external factors on the performance and representation disparities between Black and White students in college. College calculus performance was chosen as an outcome of interest due to the course's role as a gatekeeper for STEM majors and careers. The likelihood of choosing a career in STEM is chosen as the other outcome of interest. The strengths of this study include the ability to examine effects for a nationally representative sample of Black students who are matched to comparable White students on multiple factors and the ability to make stronger inferences with observational data when experimental methods cannot practically collect such data.

2.9 Guiding Motivation of Study

The position of the National Council of Teachers in Mathematics (NCTM) with respect to closing the achievement gap is that all students “should have equitable and optimal opportunities to learn mathematics free from bias,” and that “all students need the opportunity to learn challenging mathematics from a well-qualified teacher who will make connections to the background, needs, and cultures of all learners”. The solution is thus framed as an opportunity to learn. The overall aim of this study is to focus on the inequitable experiences that Black Americans have that work to

influence their performance in mathematics. So, even though all students should be afforded equal opportunities to learn mathematics, there is also a pertinent need to offer Black American students *equitable* opportunities to learn mathematics.

It is necessary to distinguish between “equity” and “equality”. In general terms, equity is defined as “the quality of being fair and impartial.” Its technical definition is “justice according to natural law or right; specifically, freedom from bias or favoritism” [Web, 2011b]. According to Secada [1994], there are two types of justice. The first type is based on written laws and ordinances, while the second type is unwritten. Secada proposes equity as one of the unwritten justices which goes beyond written laws and operates in a manner such that the application of a law does not go directly against the idea of justice [Secada, 1994]. Equality, on the other hand, is defined as “the quality or state of being equal” [Web, 2011a]. To be equal can be described as being “of the same quality or status; evenly balanced or proportioned.” Hagopian [1994] suggests that equality exists in a “polyethnic, multicultural society when culture and ethnic groups are valued positively; are ensured fundamental conditions of protection and services that enable the development of their full abilities; and are afforded unimpeded chances to vie for *positions of power and class* that fashion the conditions of life.” So, for example, when equality is present in a society, the students who fall into the top and bottom of mathematics performance will be statistically spread throughout the various racial and ethnic groups of each socioeconomic class in the society [Hagopian, 1994].

Since having access to common economic, political, and social structures of government involves the distribution of power, Atwater [2000] suggests that for different racial groups to be equal, they must have access to the same amount of power. An unequal distribution of power can lead to the oppression of certain groups over others, where oppression functions as the employment of control or power in a biased

or unjust manner [Atwater, 2000].

Many questions can be raised on the differences between equity and equality. For instance, when is equity favored over equality? When is equality desired over equity? Can true equality be obtained in the absence of equity? For example, placing two students with different academic backgrounds, one with a high number of advanced mathematics courses prior to college and the other with a lack of mathematics courses, such as algebra and trigonometry, in the same college calculus course with a high-quality instructor and the same resources would be considered equality, since they are both granted the opportunity to learn at the same level. However, the amount of learning in this calculus course will not be equal. The student with the fewer number of mathematics courses is poorly equipped in comparison to the student with more experience in mathematics courses. So, the same level and quality of instruction will be utilized differently by the two students and most likely there will be differing learning outcomes for both. Thus, in this case, while equality has been established, equity has not.

Since the absence of equity is seen as an injustice, it follows that equity involves social parity, balanced proportion, and redistribution of power, access, rights, and opportunities [Ladson-Billings, 1997]. Therefore, equity is related to the power distribution of mathematics knowledge [Atwater, 2000]. As stated previously, equality in mathematics achievement and STEM degree attainment for Black Americans has not occurred. Thus, the need for equity at the precollege level for Black Americans is necessary in order for equality to be attained at the college level. So, this work is conducted under the assumption that regardless of equality at certain time points, equity can only occur when *all* students have the opportunity to learn quality mathematics. Since uniform equality in all aspects and conditions in life is unattainable, our solution lies in seeking equitable practices in mathematics education.

Chapter 3

Methodology

This chapter will discuss in detail the methods used in this study. In particular it will highlight the data used, its collection, and the methods used to analyze the data. The statistical software `R` was used for all analyses conducted in this study [R Development Core Team, 2011].

3.1 Research Questions

The goal of this study was to compare a representative sample of Black college students who are equivalent to White college students on a number of factors found to impact achievement and participation in mathematics. Therefore, covariates related to socioeconomic status, family background, and academic preparation were considered in an attempt to understand the collective and isolated effects of external factors on the performance and participation gaps observed between Black and White students in college.

The guiding questions of this research are:

- To what extent do external factors such as community income, parental back-

ground, family support, and academic preparation help explain the Black-White performance gap in college calculus?

- What, if any, effect do these factors have on the choice of a STEM career for Black and White college students?

3.2 FICSMath Project

The data used to address the first question was drawn from the Factors Influencing College Success in Mathematics (FICSMath) Project. The goal of this project, funded by the National Science Foundation (NSF #0813702), is to identify factors that help prepare students for college calculus success. Students from across the nation at 2- and 4-year colleges and universities who enrolled in introductory college calculus were surveyed on their experiences in high school mathematics, attitude toward mathematics, career goals, prior academic performance, and demographic information. The FICSMath survey included 61 items and was administered in the Fall semester of 2009. The survey also included a section for the instructor of the course to record the student's final grade at the end of the semester. We obtained a stratified random sample of 10,437 students enrolled in 336 college calculus courses at 134 institutions.

The FICSMath Project, based out of the Science Education Department of the Harvard-Smithsonian Center for Astrophysics, is the first nationwide study of its kind to focus on and look for factors that may influence performance in college calculus. The design of this study was modeled after two previous successfully implemented projects - Project FICSS (Factors Influencing College Science Success) which began in 2002 and PRiSE (Persistence Research in Science and Engineering) which began in 2006. This type of large-scale study has the potential to address issues in a shorter

amount of time than longitudinal studies and can also gather more generalizable data than smaller-scale studies. In this epidemiological study, longitudinal data is substituted for by recall. However, self-reporting has been studied widely in college-level students and is considered highly accurate when the instrument reflects issues relevant to the respondents [Kuncel et al., 2005].

The development of the FICSMath survey was informed by several components. The first component was a comprehensive review of mathematics education literature primarily focused on variables affecting performance in high school and college level mathematics. Additionally, an extraction of a number of items dealing with prior pedagogical practices and experiences from Project FICSS and PRiSE surveys were also used in developing the instrument. Also, open-ended student responses in college calculus to questions asking them to report factors that helped them prepare for college calculus, particularly from high school mathematics courses, were used. Finally, open-ended responses from 185 mathematicians and 84 mathematics teachers from across the nation via a survey administered online were also used in composing the survey. The mathematicians responded to the question, “What can high school teachers do to prepare students for success in college calculus courses?” The mathematics teachers responded to the question, “What do you do, as a high school mathematics teacher, that you think prepares students for college calculus success?”

Content validity for the survey was established from the components used to develop the survey which reflect relevant research and information gathered from mathematics education experts, mathematicians, high school mathematics teachers, and college calculus students. In addition, the FICSMath survey was pilot tested for face validity, timing, and clarity with 45 students at two institutions and with focus groups of experts in science and mathematics education. This process helped establish a more valid instrument. Also, by pilot testing the survey, we were able to

establish that completing the survey took around 15 to 20 minutes. In order to ensure reliability of the survey, a test-retest study was conducted to analyze the stability of the instrument. This involved administering the survey to students at four universities once and then again after a two week lapse. For linear variables, the correlation coefficient between the test and retest answers served as a measure of reliability. For dichotomous and categorical variables, Cohen's kappa was used. The overall mean correlation coefficient for the instrument was 0.71 for the linear variables and the overall percent agreement was 94% for the dichotomous and categorical variables. These results from the test-retest study demonstrated symmetry between responses which implied a high level of confidence in reliability of the items on the survey.

My role in the FICSMath Project included instrument development, recruitment of the universities, and data mining. In particular, I conducted a review of mathematics education literature, gathered responses from the online survey of mathematicians and mathematics teachers, and participated in focus groups with experts in science and mathematics education in order to develop questions for the instrument. Also, I was able to use a number of statistical techniques to build models and analyze data from the project.

3.2.1 FICSMath Sample

For the sample used in the FICSMath Project, a list of colleges and universities in the US was obtained from the Integrated Postsecondary Education Data System (IPEDS) which is a system of interrelated surveys conducted annually by the US Departments National Center for Education Statistics (NCES). The list was made up of 4,305 institutions. First, the list was divided into 2-year (1,668) and 4-year (2,637) institutions and then each of the two groups was further stratified by

size of the institution (small, medium, and large). Using the institutions' undergraduate enrollment numbers, it was determined that nearly a third of the national undergraduate population attended universities and colleges that had less than 5,400 undergraduates ("small"), another third attended schools with between 5,400 and 14,800 undergraduates ("medium"), and another third attended school with more than 14,800 undergraduates ("large"). Thus, the institutions identified by the NCES were stratified by type and size into six lists: 2,089 small 4-year colleges, 348 medium 4-year colleges, 200 large 4-year colleges, 1,279 small 2-year colleges, 289 medium 2-year colleges, and 100 large 2-year colleges.

Each of the six lists of institutions was randomized. Recruiting was then conducted by going down each list and contacting the mathematics department of the school to see if they were willing to participate in the study. This was continued until we had enough schools agreeing to participate in each of the six groups. Of 276 institutions contacted, 182 (65.9%) agreed to participate. We ended up receiving usable student surveys from 134 institutions (73.6% of those who agreed to participate; 48.6% of all contacted). Of the initial institutions that agreed to participate, 73 2-year and 61 4-year returned the surveys. There were a total of 10,492 surveys returned. Table 3.1 and Table 3.2 detail the sample and response rates. Also, shown in Figure 3.1 is a map of the locations across the US of the schools in the FICSMath sample. The respondents of FICSMath were 60% male and 34% female. In terms of race and ethnicity, respondents were 66.7% White, 4.6% Black, 10.7% Asian, 0.4% American Indian/Alaskan Native, and 8.9% Hispanic.

Table 3.1: *Population Extrapolations of Calculus Students Compared with Sample Participants*

| | | Small | Medium | Large | Total |
|--------|----------------------------------|--------|--------|--------|---------|
| 2-year | Population Estimate | 2,932 | 19,342 | 16,783 | 39,057 |
| | Proportion of Overall Population | 0.018 | 0.116 | 0.101 | 0.235 |
| | Sample Size | 188 | 1,460 | 1,812 | 3,460 |
| | Proportion of Overall Sample | 0.018 | 0.140 | 0.174 | 0.332 |
| 4-year | Population Estimate | 12,140 | 66,357 | 48,698 | 127,195 |
| | Proportion of Overall Population | 0.073 | 0.339 | 0.293 | 0.765 |
| | Sample Size | 870 | 2,401 | 3,706 | 6,977 |
| | Proportion of Overall Sample | 0.083 | 0.230 | 0.355 | 0.668 |

Table 3.2: *Institutional Response Rates*

| | | Small | Medium | Large | Total |
|---------|--------------------------------------|-------|--------|-------|-------|
| 2-year | Institutions Contacted | 15 | 97 | 49 | 161 |
| | Institutions Agreeing to Participate | 12 | 54 | 28 | 94 |
| | Institutions Returning Surveys | 10 | 38 | 25 | 73 |
| | Proportion Returning/Contacted | 0.667 | 0.392 | 0.510 | 0.453 |
| 4-year | Institutions Contacted | 52 | 40 | 23 | 115 |
| | Institutions Agreeing to Participate | 36 | 35 | 17 | 88 |
| | Institutions Returning Surveys | 21 | 27 | 13 | 61 |
| | Proportion Returning/Contacted | 0.404 | 0.675 | 0.565 | 0.530 |
| Overall | Institutions Contacted | 276 | | | |
| | Institutions Agreeing to Participate | 182 | | | |
| | Institutions Returning Surveys | 134 | | | |
| | Proportion Returning/Contacting | 0.486 | | | |

3.2.2 FICSMath Subsample

For the purpose of this study, only the responses of those students who identified their race as exclusively Black or White (and ethnicity as non-Hispanic) on the survey were used. This was done in order to focus solely on the reported differences in experiences and performance between Black and White students. Also, in order to target only those students with the “American high school experience”, I excluded those students who did not attend an American high school. So, only those students who attended a high school in the US or an American school abroad were included,

Figure 3.1: *FICSMath Sample*



Red: 2-yr Small; Blue: 2-yr Medium; Purple: 2-yr Large; Green: 4-yr Small; Yellow: 4-yr Medium; Orange: 4-yr Large

while those who attended a high school in another country were not. Finally, in order to ensure validity of the responses, the student's response to the question of "Did your high school teacher spend time teaching how to solve this type of problem: Given $f(x, y) = x^4 + x^3y - 3x^2y^2 + y^4$, find $\frac{\partial}{\partial x}f(x, y)$ and $\frac{\partial}{\partial y}f(x, y)$?" were considered. If a student answered "yes" to this question, they were not included in the sample. Considering that the topic of partial derivatives is typically covered in advanced mathematics courses, well beyond the level of those taught in high schools, it is safe to assume that a student answering "yes" to this question raises validity issues for their responses. As a result of this criterion, the final sample was comprised of 5,563 students - 286 Black and 5,277 White.

3.3 Project PRiSE

The Persistence Research in Science and Engineering (PRiSE) project is a large-scale study of students from 2- and 4-year institutions which focused on identifying high school factors that influence the persistence of students in STEM disciplines. Funded by the National Science Foundation (NSF #0624444) and based out of the Science Education Department of the Harvard-Smithsonian Center for Astrophysics, this study surveyed a nationally representative sample of college and university students enrolled in introductory college English courses in the fall semester of 2007 on their interests and experiences in science. Similar to FICSMath, the sample was drawn from a stratified random sample of all the colleges and universities in the nation. Since students in college English were surveyed, the study was able to gather a more general sample of college students, both those interested in STEM fields and those who were not.

The PRiSE survey had 50 items asking students to report on their demographics, interests, high school science experiences, and family background. Many items used were drawn from an earlier survey study, FICSS, of students enrolled in introductory college science courses that underwent rigorous validation and reliability analysis [Sadler and Tai, 2007]. To establish validity of the PRiSE survey, multiple methods were used. First, face and content validity of the survey were obtained through focus groups with STEM education experts and students. In addition, open-ended free response questionnaire data from 412 science teachers and scientists served to support content validity because the PRiSE survey incorporated the breadth of views and hypotheses held by practitioners in the field that were gleaned from these questionnaires. To ensure the item choices reflected the variation in experiences of students, the survey was also pilot-tested with 49 students so that items and scales

could be adjusted for the final survey to appropriately capture the natural variability in the sample. Test-retest reliability of the survey was established by administering the survey to 96 students twice over an interval of two to three weeks. For continuous variables, the correlation coefficient between the test and retest answers served as a measure of reliability; for dichotomous variables, Cohen's kappa was used. The overall mean correlation coefficient of the survey was 0.70. In the case of identification of career interest, test-retest agreement was 87.2% between the two administrations of the survey. These results from the test-retest study demonstrated symmetry between responses which implied a high level of confidence in reliability of the items on the survey.

My role in Project PRiSE consisted only of data mining.

3.3.1 PRiSE Sample

Similar to FICSMath, for the sample used in the PRiSE Project, a list of post-secondary institutions was provided by the NCES. The list comprised 3,779 institutions, 1,616 2-year and 2,163 4-year. These two groups were further stratified, again similar to FICSMath, by the undergraduate enrollment numbers into small, medium, and large. So, the institutions identified by the NCES were stratified by type and size into six lists: 1,732 small 4-year colleges, 297 medium 4-year colleges, 134 large 4-year colleges, 1,227 small 2-year colleges, 298 medium 2-year colleges, and 91 large 2-year colleges.

Each of these six lists of institutions was randomized. Schools without science majors were excluded. Recruiting was then conducted by going down these lists until enough positive responses were received that a sufficient number of students in the respective category could be reached. To prevent the possibility of students

from any single institution constituting a substantial fraction of the sample, a cap of 500 students per institution was imposed. Of the 160 institutions contacted during recruiting, 43 (26.9%) agreed to participate. Usable student surveys from 34 (79.1% of those agreeing to participate and 21.3% of all contacted institutions) were received. Of the 6,860 students in the sample, 56.4% attended 4-year institutions and 43.6% attended 2-year institutions. Figure 3.2 displays the locations across the US of the institutions that participated in the study. The respondents of PRiSE were 57% female and 43% male. In terms of race and ethnicity, the respondents were 73% White, 9% Black, 9% Asian, and 12% Hispanic.

Figure 3.2: *PRiSE Sample*



3.3.2 PRiSE Subsample

Similar to the FICSMath subsample, in order to focus solely on the reported differences in experiences and performance between Black and White students, only the responses of those students who identified their race as exclusively Black or White

(and ethnicity as non-Hispanic) on the survey are used. As a result, the final sample comprised 5,168 students - 540 Black and 4,628 White.

3.4 Dealing With Missing Data

Missing data, a pervasive problem in many studies, was an issue in this particular study. Respondents did not answer every question and thus we were left with incomplete data sets. Three major problems with incomplete data are (1) loss of information or power due to loss of data; (2) complication during data management and analysis, partially because of limitations with standard statistical software; and (3) potential marked bias because of systematic differences between observed and missing values [Cole, 2007]. Most statistical analysis methods assume the absence of missing data and are only able to include observations which are complete, or for which all variables are measured. In order to obtain a complete data set, with no missing observations, it is necessary to either remove all records with a missing observation (listwise deletion) or impute the data (replace missing data with an estimate of its value). In the presence of missing data, most statistical software use listwise deletion before conducting any analysis. However, imputation is the better choice since it allows you to appropriately use all the information present in the dataset, and avoid the biases, inefficiencies, and incorrect uncertainty estimates that can result from dropping all partially observed observations from the analysis [Honaker et al., 2009].

For the sake of this study, multiple imputation, powered by the **R** package **Amelia** [Honaker et al., 2010], was utilized to deal with missing observations. Multiple imputation has been shown to reduce bias and increase efficiency compared to listwise deletion [Honaker et al., 2009]. Essentially, multiple imputation involves imputing n values for each missing observation in the data set and thus creates n complete data

set. Within these complete data sets, the observed values (i.e., those not missing) are the same but the missing observations have been filled in with imputations that reflect the uncertainty about the missing data.

Multiple imputation uses a three-step process to handle missing data. First, the missing data is imputed through a Bayesian procedure. As mentioned previously, the key to multiple imputation is the creation of more than one data set during the imputation stage, thus providing a means of determining the bias associated from imputing [Cole, 2007]. During this step it is important to identify the variables to include in the imputation model. Any variable that will be in the analysis model should be included in the imputation model. It is also useful to add more information to the imputation model than will be present in the actual analysis. Since imputation is predictive, any variables that would increase predictive power should be included in the model [Honaker et al., 2009]. Additionally, the first step involves deciding how many imputed data sets should be created. While generally a small number of imputations ($n \leq 5$) is adequate for most situations, Rubin [Rubin, 1987] provided a formula for determining the efficiency of n imputations given a percentage of missing data,

$$\left(1 + \frac{\gamma}{n}\right)^{-1},$$

where γ is the percentage of missing information, which is less than or approximately equal to the percentage of missing data. So, for example, with this formula you can see that with 20% missingness, 94% efficiency is obtained with three imputed datasets, 96% with $n = 5$, and 98% with $n = 10$. So, one should determine what level of efficiency is desired and then determine how many imputed data sets will be necessary given the amount of missingness in the data. Now, in the calculation of

the imputed values, it is important to note that the imputation is not necessarily to determine what a respondent would have answered if they had given us the data but rather to preserve important characteristics of parameters (e.g., means, variances, covariances, etc.) and distributions [Cole, 2007]. So, the imputed values in multiple imputation serves a primary purpose of creating an efficient and unbiased manner to properly evaluate all of the observed data in the data set.

The next step of multiple imputation involves analysis of each imputed data set. So, once n data sets have been created with imputed values, statistical analyses are run once for each of the n data sets. The results from these analyses will then be used to guide calculations in the next step. The third step involves the combination of the results obtained from the analyses run on the n imputed sets of data. This step contains three tasks: (1) Calculate the means for all relevant parameter values, (2) calculate standard errors for all relevant parameters, and (3) calculate p -values for the parameters based on a modified degrees of freedom formula [Cole, 2007].

For the FICSMath data the fraction of missingness is $\gamma = 0.02081$. Therefore, using the formula given above, 99.3% efficiency is obtained with the use of $n = 3$ imputed datasets. As mentioned previously, since imputation is predictive, any variable that can strengthen the predictive power should be used in the model. Thus, any variable in the FICSMath dataset that can be conjectured to influence performance in college calculus was used in the imputation model. Of course, variables related to the external factors of academic preparation, SES, and family background were included in the model since they are the variables of focus which will be used in the analyses. Additionally, variables dealing with students' high school mathematics classroom practices and pedagogies, high school mathematics classroom environment, and interest in mathematics were predictors in the model used to create the imputed values. Finally, analyses were run on each of the three imputed datasets and the

results combined to produce final results.

For the PRiSE data the fraction of missingness is $\gamma = 0.06267$. Therefore, using the formula given above, 98% efficiency is obtained with the use of $n = 3$ imputed datasets. Any variable in the PRiSE dataset that can be theorized to influence the likelihood of choosing a career in STEM were used in the imputation model. Again, variables related to the external factors of SES, family background/support, and academic preparation were also included in the imputation model. Finally, variables dealing with factors in career satisfaction, performance in middle school and high school mathematics and science courses, interests in science, and prior experiences in science were also predictors in the model used to create the imputed values.

3.5 Analyses

Since one of the goals of this study is to assess the extent to which certain external factors help explain the performance difference in college calculus between Black and White students, a comparison of the two groups of students is necessary. However, as mentioned earlier, the drawback of most studies which compare Black and White students on some measure of performance is the lack of truly comparable groups. So, in an effort to answer the first research question I wanted to compare the mean college calculus performance of Black and White students with similar backgrounds. More specifically, I wanted to compare groups of Black and White college students coming from similar SES, academic preparation, and family backgrounds.

The use of observational data tends to limit the conclusions drawn from analyses used to compare groups since participants are not randomly assigned to a treatment which minimizes the effect of confounding variables. In other words, since observational data captures the natural variation in a population, there could be

multiple variables that affect the differences observed between groups, particularly since group differences may be due to some confounding variable(s) attributed to being a member of a group. However, observational data allows greater flexibility in collecting information on factors that cannot be manipulated in an experimental setting, randomly sampling from representative populations, and gathering data from larger groups thereby increasing statistical power. While capitalizing on these strengths, propensity score matching (PSM) is an analytic method that allows the use of observational data to derive causal relationships such as those arrived at through experimental designs. The propensity score is an estimate given to each individual based on the probability of being in one condition rather than another given a set of covariates. The individuals with the same propensity score estimate are then split into two groups. This results in two groups balanced on the covariates used to create the propensity score estimates.

Matching is becoming an increasingly popular method of causal inference in many fields from statistics [Rubin, 2006, Rosenbaum, 2002] to law [Rubin, 2001]. The motivation for focusing on propensity score matching methods is that in this study the dimensionality of the observable characteristics is high. With a small number of characteristics (e.g., two binary variables), matching is straightforward (one can simply group units into four categories). However, in the presence of many variables it can be difficult to determine the dimensions along which to match. So, under such circumstances, matching on the propensity score is especially useful because they provide a natural weighting scheme that yields unbiased estimates of treatment impact [Dehejia and Wahba, 2002]. Other studies have employed a design similar to this study also using PSM. For example, a study was conducted utilizing PSM to compare the mathematics achievement of immigrant Mexican Americans to other students matched on school and family background characteristics [Crosnoe, 2005].

In this study, the status of being Black is treated as one group while the status of being White is the other. The students' final grade in college calculus and the likelihood of choosing a career in STEM will serve as the outcome variables and the students' socioeconomic status, family support, and academic preparation will be the categories on which the two groups are matched. Detailed information about each variable used is given below.

3.5.1 Variables used for FICSMath Analysis

The outcome variable for the analysis conducted for the first research question is students' final grade in introductory college calculus (`q62grade100`). The instructor of each calculus course filled in the final letter and number grade for each student at the end of the semester before sending the surveys back to us. This variable takes on values between 0 and 100. For those cases where the professor only provided a letter grade or if in the rare case the student was awarded a "Pass" instead of a letter grade, the grade was converted into a grade on the 100-point system. The scale was: $A+ = 98$, $A = 94.5$, $A- = 92$, $B+ = 88$, $B = 84.5$, $B- = 81$, *etc.* and "Pass" = 83. The number conversion for "Pass" was done by comparing students with equivalent other math scores. Then the average calculus grade for those students was used.

The group variable is based on the race of the student. For this study we only consider those students who identified their race as Black or White. So, a dichotomous variable is utilized, (`race`), where it takes on the value "0" for White and "1" for Black. Note that the assignment of Black or White is exclusive, so those students indicating more than one race or ethnicity (e.g., White-Hispanic) on the survey were not included.

The covariates used to match on are mapped to the following categories of so-

cioeconomic status, academic preparation, or family background. The socioeconomic status variables are:

- Median Household Income by ZIP code (`zp_medhhncm`) - This is a linear variable taking on values between 0-185,466. On the survey, we asked the students to “provide your home ZIP code (when you graduated from high school)” and using data from the US Census 2000 we were able to obtain the community’s median household income based on the ZIP code.
- Highest Level of Education of Male Parent or Guardian (`q54edfath`) - This variable takes on values between 0-4. The categories are linearized as “0”=“did not finish high school”, “1”=“high school”, “2”=“some college”, “3”=“four years of college”, and “4”=“graduate school”.
- Highest Level of Education of Female Parent of Guardian (`q55edmoth`) - This variable takes on values between 0-4. The categories are linearized as “0”=“did not finish high school”, “1”=“high school”, “2”=“some college”, “3”=“four years of college”, and “4”=“graduate school”.

The family support variables are:

- Home Environment Supportive of Math (`q52homesup`) - This is a scale variable indicating the degree to which home environment was supportive of mathematics. It takes on whole number values between 0-5, with “0”=“not supportive at all” and “4”=“very supportive”.
- Family Interest in Mathematics (`q57career`; `q57help`; `q57noint`) - These are all dichotomous variables taking on value “1” if selected by the student. Respectively they represent, “Math is a way for you to have a better career”, “My

parents were able to help me with math”, and “Math was not an interest of my family”.

- People Who Encouraged Student to Take Math Courses (`q53none`; `q53fath`; `q53moth`) - These are each dichotomous variables taking on value “1” if selected by the student. Respectively they represent, “No one”, “Father/Male guardian”, and “Mother/Female guardian”.

The academic preparation variables are:

- SAT/ACT Math Score (`q58act_satm`) - This is a scaled variable with values between 200-800. Some students reported scores for the ACT instead of the SAT. So, these scores were converted to SAT scores using an ACT/SAT concordance model identified by the College Board.
- Grade in Most Advanced Math Course (`HighestMathGrade`) - This scaled variable takes on values between 0-4.33. Students were asked to report on the mathematics courses taken in high school and their final grade in these courses. So, this variable indicates their final grade in their most advanced high school mathematics course. The scale was $A+ = 4.33, A = 4, A- = 3.67, B+ = 3.33, \dots, F = 0, P = 2.8$.
- Number of High School Mathematics Courses Taken (`NumberOfMathClasses`) - This linear variable takes on values between 0-11. It is created by counting the number of mathematics courses reported by the student as having completed during high school.
- People Who Encouraged Student to Take Math Courses (`q53couns`; `q53mathteach`; `q53othteach`) - These are each dichotomous variables taking on value “1” if se-

lected by the student. Respectively they represent, “School counselor”, “Math teacher”, and “Other teacher”.

- Quality of Mathematics Teacher (**teacherquality**) - This is a linear variable with values between 1-6. This variable was created by averaging the students’ ratings of six items on the characteristics of their high school mathematics teacher. The students were asked to rate their teacher on “Was enthusiastic about mathematics”, “Treated all students with respect”, “Used graphs, tables, and other illustrations”, “Highlighted more than one way of solving a problem”, “Made mathematical errors”, and “Explained ideas clearly”. The scale ranged from “1”=“low” to “6”=“high”. Note that the item “Made mathematical errors” was reverse coded before creation of the new variable in order to maintain consistency of the responses.
- Year in College (**q50collyear**) - This is a variable with values between 1-6. The categories are “1”=“freshman”, “2”=“sophomore”, “3”=“junior”, “4”=“senior”, “5”=“graduate student”, and “6”=“other”.

In order to achieve better balance between the two groups of students, the variable gender, **q46gender**, was also used to match on. This is a dichotomous variable with “1” representing male and “0” representing female.

There were other items on the FICSMath survey that were considered as falling under the categories of family support and academic preparation. However, after including them in the model it was found that these variables did not match well or caused other matchings to become worse and were therefore removed. These variables included whether the student had taken calculus in high school or previously in college, and if their sibling, other relative, or coach encouraged them to take mathematics courses. As a result, the variables listed above are the variables which yielded the

best matching and thus, the best balance between the two groups of students.

3.5.2 Variables used for PRiSE Analysis

Next, in an effort to answer the second research question, the data from Project PRiSE was utilized. Using the propensity score matching method again, the two comparison groups were made up of Black (non-Hispanic) and White (non-Hispanic) students. Similar covariates dealing with socioeconomic status, academic preparation, and family background were used to match on. Again, detailed information about each variable is given below. For this analysis instead of using a measure of performance as the outcome variable, the likelihood of choosing a career in a STEM field was used.

This outcome variable was created with the use of four other variables on the PRiSE survey. These four items asked the student to rate their likelihood of choosing a career in life sciences, physical sciences, engineering/technology, and mathematics (`q39lifsi`, `q39physi`, `q39eng`, and `q39math` respectively). The ratings ranged from “1”=“not at all likely” to “6”=“extremely likely”. The new variable, `STEM_proxy`, was created by assigning the maximum rating reported by the student across each of the four items (i.e., $\text{STEM_proxy} = \max(\text{q39lifsi}, \text{q39physi}, \text{q39eng}, \text{q39math})$). The distributions of the ratings for each of the four items for Black and White students are given in Table 3.3. Also, the mean ratings for each group across the career choices are illustrated in Figure 3.3.

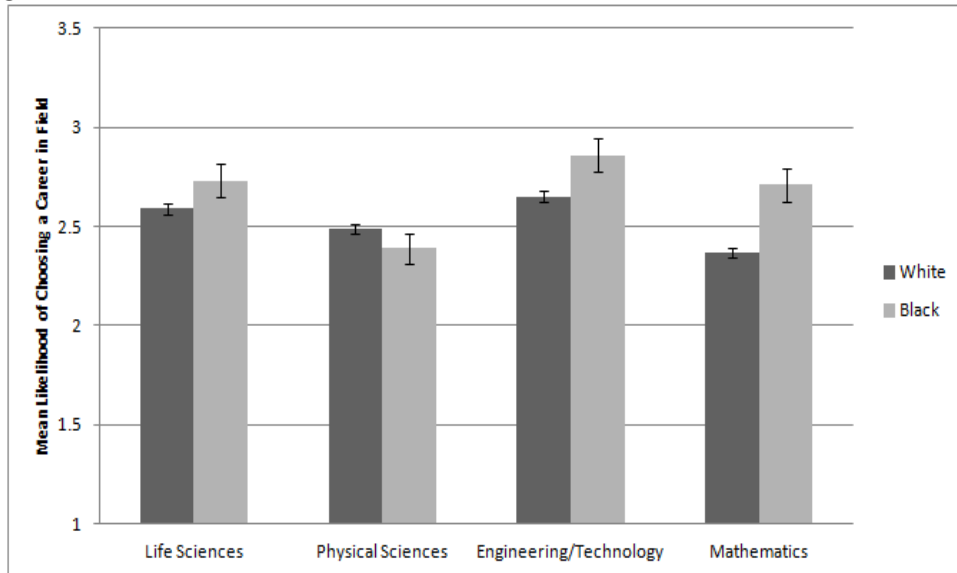
Validity of this created variable was tested by constructing a logistic regression model with `STEM_proxy` as a predictor and desired career in college as the outcome variable. The variable `q1colprofexp` was recoded to a dichotomous variable with “1” representing a choice of a STEM career in college and “0” representing a non-

STEM career choice in college. The logistic regression indicated that `STEM_proxy` was a significant predictor of STEM career in college ($p < 0.001, \beta = 0.80761$). Thus, it was concluded that the created variable was a valid proxy for the likelihood of choosing a career in STEM.

Table 3.3: *Distribution of Student Ratings for Likelihood of Choosing a Career in STEM*

| | White | | | | | |
|----------|-------|-----|-----|-----|-----|-----|
| Career | 1 | 2 | 3 | 4 | 5 | 6 |
| q39lifsi | 41% | 17% | 13% | 10% | 10% | 9% |
| q39physi | 42% | 16% | 14% | 12% | 10% | 6% |
| q39eng | 43% | 14% | 12% | 10% | 9% | 12% |
| q39math | 48% | 14% | 11% | 12% | 10% | 5% |
| | Black | | | | | |
| Career | 1 | 2 | 3 | 4 | 5 | 6 |
| q39lifsi | 43% | 10% | 14% | 10% | 11% | 13% |
| q39physi | 48% | 12% | 14% | 10% | 9% | 6% |
| q39eng | 42% | 10% | 8% | 13% | 10% | 16% |
| q39math | 44% | 9% | 12% | 12% | 12% | 11% |

Figure 3.3: *Mean Ratings for Likelihood of Choosing a Career in a STEM Field*



An attempt was made to construct a model for the likelihood of choosing a

career in STEM which resembled that of the performance model. The idea was to use covariates similar or equivalent to those used in the performance model. Since the primary focus of PRiSE was on the students' science experiences (chemistry, biology, and physics), variables dealing with family support and academic preparation from the PRiSE survey were mainly related to science (as opposed to mathematics for the FICSMath survey) . However, there were a few variables that dealt with mathematics experiences in high school. In the PRiSE data, while there is no variable for community median household income, there does exist a variable for the annual per capita income by ZIP code and therefore, this variable was used. Also, PRiSE did not include an item on whether or not the student's parents were able to help them with science. Although items dealing with who encouraged the student to take science courses, overall quality of science teacher, and their current year in college were present on the PRiSE survey, these variables did not match well in the career choice model.

The covariates used to match on in the career choice model are mapped to the following categories of SES, family support, and academic preparation. The socioeconomic variables are:

- Annual Per Capita Income by ZIP Code (`zp_pcapincm`) - This is a linear value taking values between 0-97,178. On the survey, the students were asked to provide their home ZIP code and using data from the US Census 2000 the community annual per capita income was obtained.
- Highest Level of Education of Male Parent or Guardian (`q47hpemrecode`) - This variable takes on values between 0-4. The categories are linearized as “0”=“less than high school diploma”, “1”=“high school diploma/GED”, “2”=“some college/associate degree”, “3”=“bachelor’s degree”, and “4”=“master’s degree or

higher”.

- Highest Level of Education of Female Parent or Guardian (**q47hpefrecode**)
 - This variable takes on values between 0-4. The categories are linearized as “0”=“less than high school diploma”, “1”=“high school diploma/GED”, “2”=“some college/associate degree”, “3”=“bachelor’s degree”, and “4”=“master’s degree or higher”.

The family support variables are:

- Home Environment Supportive of Science (**q45suprt**) - This is a scale variable indicating the degree to which the home environment was supportive science, (“for example, did you often visit science museums, or zoos?”). It takes on whole number values between 1-5, with “1”=“not supportive”, “2”=“occasionally supportive”, “3”=“moderately supportive”, “4”=“generally supportive”, and “5”=“very supportive”.
- People Who Encouraged Student to Take Science Courses (**q46noone**; **q46dad**; **q46mom**) - These are each dichotomous variables taking on value “1” if selected by the student. Respectively they represent, “No one”, “Father/Male guardian”, and “Mother/Female guardian”.
- Family Interest in Science (**q49bettr**; **q49noint**) - These are dichotomous variables taking value “1” if selected by the student. Respectively they represent, “Family viewed science as a way for you to have a better career” and “Science was not a family interest”.

The academic preparation variables are:

- SAT/ACT Math Score (**q12act_satm**) - This is a scaled variable with values between 200-800. Some students reported scores for the ACT instead of the SAT.

so, these scores were converted to SAT scores using an ACT/SAT concordance model identified by the College Board (1999).

- Grade in Highest Math Taken (**q11himg**) - This scaled variable takes on variable values between 0-4.33. Students were asked to report on their final grade for their most advanced math course taken in high school, so this grade is indicated by the variable. The scale was $A+ = 4.33$, $A = 4$, $A- = 3.67$, $B+ = 3.33, \dots, F = 0$.
- Total Number of Math Courses Taken in High School (**q10totlm**) - This linear variable takes on values between 0-9. It was created by counting the number of mathematics courses reported by the student as having completed during high school.

Again, to achieve better balance between the two groups of students, the variable **gender**, **q40gender**, was also used to match on. This is a dichotomous variable with “1” representing male and “0” representing female. Also, the R package **Matching** was utilized for matching achieving balance on the covariates for each model [Sekhon, 2011].

Chapter 4

Results: Achievement Differences

This chapter will summarize the results of the analyses for the first research question: To what extent do external factors such as socioeconomic status, family support, and academic preparation help explain the Black-White performance gap in college calculus? The benefit of constructing collective and relative models is discussed and the results from each model are presented. Also, I present the steps taken in order to combine the data sets obtained from multiply imputing the original data set.

4.1 Models for Matching

As stated previously, the primary analysis used in this study was propensity score matching. Propensity score matching was the method of choice for this study due to its ability to allow comparisons between two groups that are balanced on particular covariates. It is the optimal statistical technique for this study given the study's use of observational data and the goal of evaluating factors that cannot be practically manipulated or controlled in experimental designs. Therefore, the benefits

of using observational data are taken advantage of with the use of matching.

The results of the matching are discussed in the next few sections. Although I constructed one overall model to test the collective effect of all the covariates on performance in college calculus courses, I also chose to construct separate models to assess the relative effects of the covariates. While it is recognized that students are not exposed to isolated experiences, but rather concurrent ones, it is still beneficial to know the relative effects for each of the four groups of covariates (e.g. SES, family support, academic preparation). For each model, variables that mapped into the groups under consideration were chosen as the covariates and matched on in order to achieve balance between the two groups of students.

4.2 Combining the Results

The multiple imputation step produced three complete data sets. Therefore, the matchings for each model had to be conducted for each individually imputed data set. In order to combine the results of the matchings for each three data sets, the rules presented by Cole [2007] were used. Combining the results involved three parts: (1) calculating the means for the parameter estimates, (2) calculating the standard errors for the parameters, and (3) calculating the p -values for the parameters.

Calculating overall parameter estimates was the most straightforward step as the parameter values were summed across the three data sets and this sum was divided by 3 (i.e. average parameter estimate), as in Equation 4.1,

$$\overline{Q} = \frac{1}{3} \sum_{i=1}^3 \hat{Q}_i, \quad (4.1)$$

where \hat{Q}_i is the parameter estimate for the i th imputed data set. Next, the within-

imputation variance was calculated with Equation 4.2,

$$\overline{U} = \frac{1}{3} \sum_{i=1}^3 \hat{U}_i, \quad (4.2)$$

where \hat{U}_i is the variance estimate for the i th imputed data set. The between-imputation variance was also calculated using Equation 4.3,

$$B = \frac{1}{3} \sum_{i=1}^3 (\hat{Q}_i - \overline{Q})^2. \quad (4.3)$$

The total variance was found by combining the within- and between-variances by Equation 4.4,

$$T = \overline{U} + \left(1 + \frac{1}{3}\right) B. \quad (4.4)$$

To obtain the standard error for the parameter of interest, the square root of T for that parameter was taken [Rubin, 1987].

Finally, the degrees of freedom were acquired by using Equation 4.5. Using the degrees of freedom and the t -value calculated by Equation 4.6, the p -value was found,

$$df = (3 - 1) \left[1 + \frac{\overline{U}}{\left(1 + \frac{1}{3}\right) B} \right]^2, \quad (4.5)$$

$$t \approx \frac{\overline{Q}}{\sqrt{T}}. \quad (4.6)$$

Utilizing these equations, the results from the matchings for each model were

combined for all three complete data sets. These combined results are presented in the next few sections.

4.3 The Overall Model

For the overall model, each of the 19 variables presented in the previous chapter were chosen as the covariates desired to match and achieve balance on. The result of the matching proved to be worthwhile. Table 4.1 summarizes descriptive statistics for the covariates before and after matching for both groups of students. For each covariate, there were significant differences in the responses between the groups of Black and White students before matching. However, after one-to-one matching, the groups were balanced with no significant differences on these covariates.

Table 4.1: *Performance Model: Covariate means before and after matching*

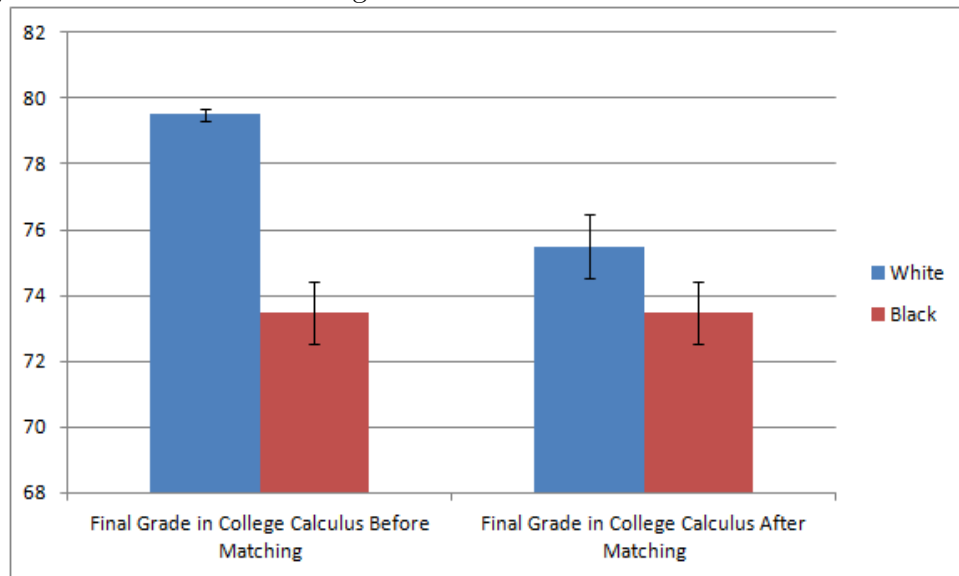
| | Black Mean n=286 | White Mean Before n=5,277 | White Mean After n=286 |
|---|---------------------|------------------------------|---------------------------|
| Covariates | | | |
| Gender (0=female; 1=male) | 55% | 66%*** | 56% |
| SOCIOECONOMIC STATUS | | | |
| Median Household Income | \$45,537 | \$52,340*** | \$46,730 |
| Father's Education Level [†] | 2.11 | 2.48*** | 2.13 |
| Mother's Education Level [†] | 2.27 | 2.45** | 2.22 |
| FAMILY SUPPORT | | | |
| Home Environment Supportive of Math [◊] | 3.38 | 3.90*** | 3.47 |
| Math is a way to a better career | 44% | 52%* | 42% |
| My parents were able to help me with math | 22% | 34%*** | 23% |
| Math was of no interest to my family | 25% | 17%** | 25% |
| No one encouraged me to take math classes | 51% | 38%*** | 51% |
| Mother encouraged me to take math classes | 27% | 40%*** | 26% |
| Father encouraged me to take math classes | 20% | 41%*** | 23% |
| ACADEMIC PREPARATION | | | |
| SAT/ACT Math Score | 535 | 609*** | 541 |
| Grade in most advanced math course | 3.10 | 3.38*** | 3.15 |
| Number of HS math courses taken | 4.10 | 4.27* | 4.06 |
| School counselor encouraged me to take math classes | 25% | 32%** | 26% |
| Math teacher encouraged me to take math classes | 27% | 34%** | 24% |
| Other teacher encouraged me to take math classes | 5% | 8%** | 4% |
| Overall quality of teacher | 3.67 | 3.65 | 3.70 |
| Current year in college ^Δ | 2.09 | 1.85** | 2.13 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; †: 0=Did not finish high school, 1=High school, 2=Some college, 3=Four years of college,

4=Graduate school; ◊: 0=Not supportive at all; 6=Very supportive; Δ: 1=Freshman, 2=Sophomore, 3=Junior, 4=Senior

Before matching, Black students performed significantly worse in their college calculus courses in comparison to the White students ($p < 0.001$). On a 100-point scale, Black students earned an average grade of 73.5, while White students earned an average final grade of 79.5. However, after matching on each of the covariates listed in Table 4.1, the difference between the two groups decreased from 6 points to 2 points. This is illustrated in Figure 4.1. So, while the group of 286 Black students remained the same (with a final grade average of 73.5), the group of 286 White students with similar backgrounds to the Black students earned an average final grade of 75.5. It is important to note that this difference is now non-significant with a p -value of 0.1903.

Figure 4.1: *Difference in College Calculus Performance Before and After Matching*



Without considering error, these results indicate that the variables used to match the two groups explain 66.67% of the difference in final grades seen between Black and White students in college calculus courses. While there still exists about 33.3% of the difference that has not been explained by the chosen covariates, it is important to highlight that the difference is now non-significant. Technically speaking,

this means that the null hypothesis of the performance in college calculus difference between the two groups of students being zero is not rejected. So, the claim that there exists no difference between Black and White students in college calculus performance is accepted.

4.4 The Isolated Effects

In order to assess the isolated effects of each group of covariates, separate models were constructed. There were a total of four models, one for each group of covariates (including gender), and balance on the specified covariates was achieved for each one. The results of these separate models are presented in the next four subsections and are illustrated in Figure 4.5.

4.4.1 Gender

For the Gender model, only one variable, `q46gender`, was used as the covariate to match and achieve balance on. Before any matching there was a 6 point difference (Cohen's $d = 0.39$) in the average final grade between the group of Black and White students ($p < 0.001$). After matching solely on gender, that difference increased by 0.87 of a point to a difference of 6.87 points (Cohen's $d = 0.44$), $p < 0.001$. This increase in difference is likely due to the fact that before matching there are significantly more males in the group of White students (66%) than in the group of Black students (55%). Therefore, without using gender as a covariate to match on, there is a greater likelihood that a Black female will be matched to a White male. Since the difference in performance between White males (78.2) and Black males (72.3) is greater than the difference between White males and Black females (74.7), once we match on gender, each Black male is now matched with a White male thereby

extracting the effect of gender. This is consistent with finding a greater difference in performance after using gender as a covariate.

4.4.2 Socioeconomic Status

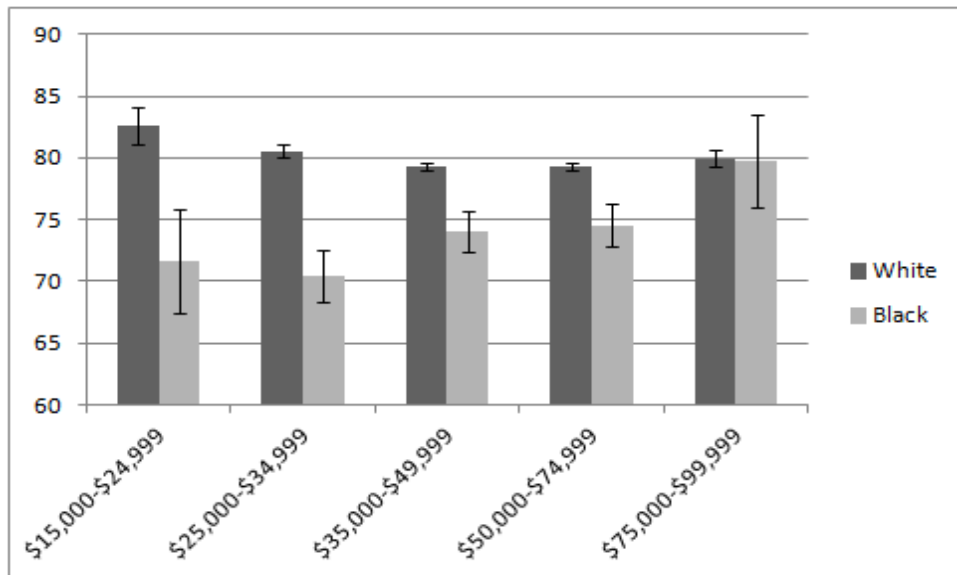
For the Socioeconomic Status (SES) model, three variables were used as the covariates to match and achieve balance on: `zp_medhhncm`, `q54edfath`, and `q55edmoth`. After matching and achieving balance on these three variables, the difference between the two groups increased by 1.06 points to a difference of 7.06 points (Cohen's $d = 0.46$), $p < 0.001$. So, matching only on the SES variables yielded a 17.7% increase in the difference between White and Black students' performance in college calculus.

A closer look at the three covariates used may help to explain this increase in difference. Figure 4.2 illustrates the mean final grades in college calculus across the different median community income levels for both groups of students. It is observed that the White students in the lowest income level are actually performing slightly better than White students in the higher income levels. Also, the differences in the average grade between White and Black students are higher at the lower income levels than at the other levels. So, when matching on the SES variables, low-income Black students are being matched to low-income White students, therefore likely leading to the increase in difference seen after matching. In addition, the mean performance differences for different levels of mother and father's education are higher at the "high school" and "some college" levels respectively (see Table 4.2). It is noted that a larger percentage of Black students are in the lower income levels than for White students. The same is true for the lower parental education levels.

Again, when the groups of students are matched on the SES covariates, Black and White students with similar parental education levels are matched and thereby

leading to the difference increase. It is also observed that while there seems to be an upward trend in the average grades for Black students across the levels of income, this trend is not directly obvious for the group of White students. There is a similar upward trend for both groups for the mother's education, however, this trend is not apparent for father's education. These findings, which are illustrated in Figures 4.3 and 4.4, will be discussed more in the discussion chapter.

Figure 4.2: *Mean Calculus Performance at Community Income Levels for FICSMath Sample*



4.4.3 Family Support

For the Family Support model, seven variables were used: q52homesup, q57career, q57help, q57noint, q53none, q53moth, and q53fath. After matching and achieving balance on these variables, the difference decreased by .81 of a point to a difference of 5.19 points (Cohen's $d = 0.34$), $p < 0.001$. This means that the family support variables explain about 14% of the observed performance difference between the two groups when isolated.

Figure 4.3: Mean Calculus Performance for Father's Education Level for FICSMath Sample

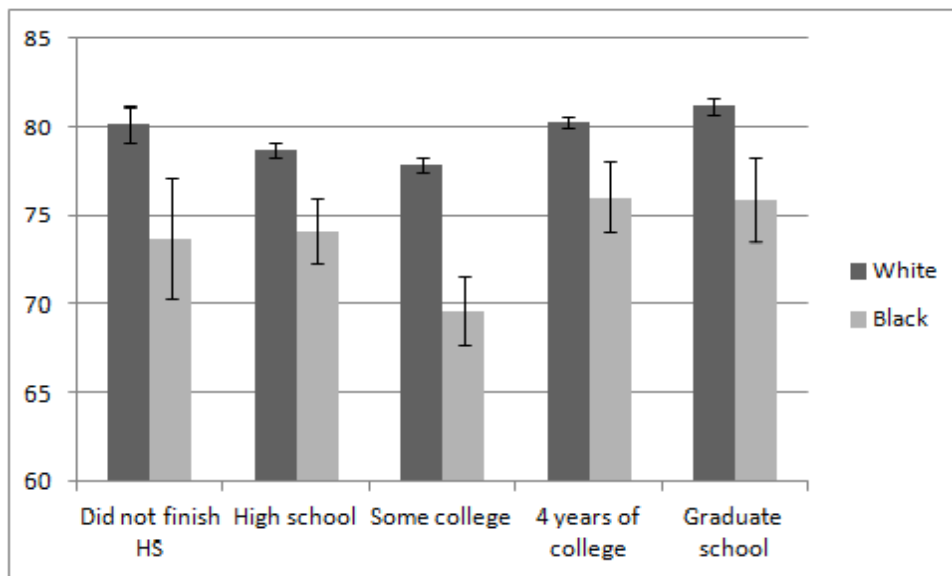


Figure 4.4: Mean Calculus Performance for Mother's Education Level for FICSMath Sample

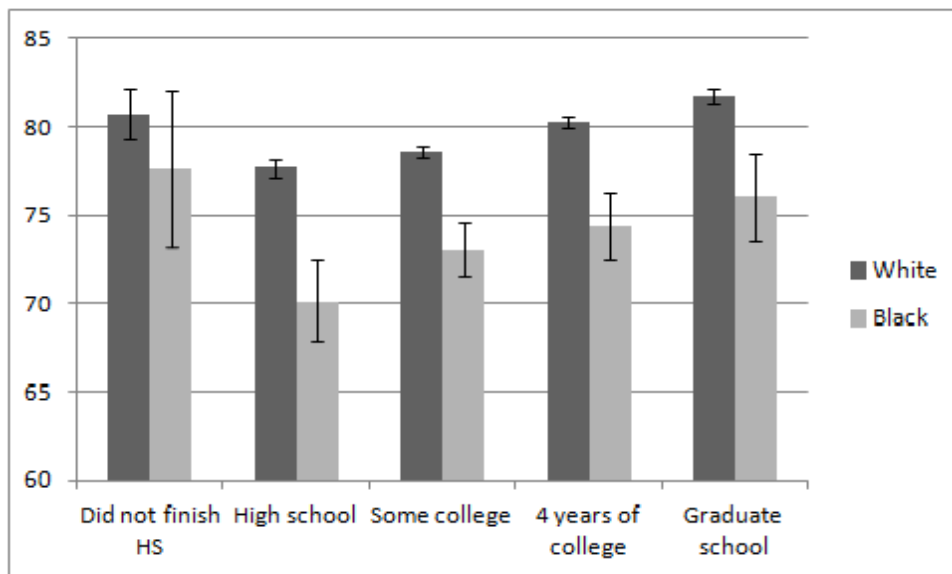


Table 4.2: *Mean Calculus Performance of Black & White Students by SES Covariates*

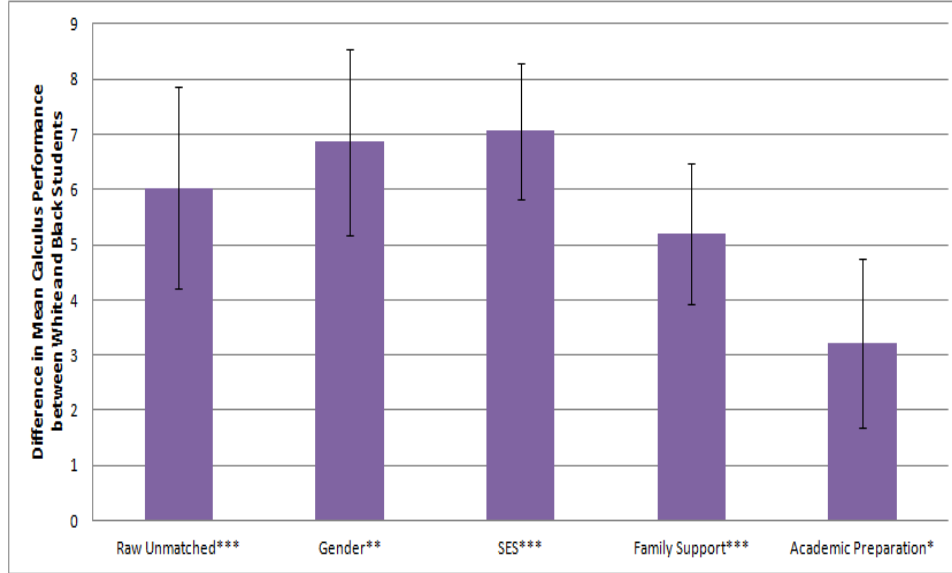
| SES Covariates | | White | | Black | | Difference |
|-------------------------|--------------------|-------|-----|-------|-----|------------|
| | | Mean | % | Mean | % | |
| Median Household Income | Under \$15,000 | 40 | 0% | 80 | 0% | -40 |
| | \$15,000-\$24,999 | 82.59 | 1% | 71.65 | 8% | 10.94 |
| | \$25,000-\$34,999 | 80.54 | 16% | 70.48 | 22% | 10.06 |
| | \$35,000-\$49,999 | 79.29 | 34% | 74.07 | 32% | 5.22 |
| | \$50,000-\$74,999 | 79.3 | 37% | 74.53 | 31% | 4.77 |
| | \$75,000-\$99,999 | 79.91 | 9% | 79.75 | 6% | 0.16 |
| | \$100,000 and over | 81.21 | 3% | 84.5 | 0% | -3.29 |
| Father's Education | Did not finish HS | 80.18 | 2% | 73.71 | 7% | 6.47 |
| | High school | 78.67 | 20% | 74.16 | 25% | 4.51 |
| | Some college | 77.87 | 24% | 69.69 | 30% | 8.18 |
| | 4 years of college | 80.29 | 32% | 76.07 | 22% | 4.22 |
| | Graduate school | 81.16 | 21% | 75.89 | 16% | 5.27 |
| Mother's Education | Did not finish HS | 80.7 | 1% | 77.64 | 4% | 3.06 |
| | High school | 77.66 | 19% | 70.12 | 20% | 7.54 |
| | Some college | 78.6 | 29% | 73.03 | 36% | 5.57 |
| | 4 years of college | 80.29 | 35% | 74.3 | 23% | 5.99 |
| | Graduate school | 81.75 | 16% | 76.06 | 17% | 5.69 |

4.4.4 Academic Preparation

For the Academic Preparation model, eight variables were used: `q58act_satm`, `HighestMathGrade`, `NumberOfMathClasses`, `q53couns`, `q53mathteach`, `q53othteach`, `teacherquality`, and `q50collyear`. After matching and achieving balance on these variables, the difference decreased by 2.78 points to a difference of 3.22 points (Cohen's $d = 0.21$), $p < 0.05$. This result indicates that the group of academic preparation variables account for 46% of the performance difference seen between Black and White students in college calculus. Therefore, this isolated model was able to explain the largest proportion of difference of the four models. It should also be noted that the difference seen after matching on these covariates, while still significant at the 0.05 level, is the least significant difference of the four separate models. Additionally, the standard errors of each of the difference estimates imply that the isolated effect of the academic preparation covariates is significantly different from the isolated effects

of both gender and the SES covariates, whereas family support is not. This suggests that the group of academic preparation covariates explains significantly more of the performance difference seen between Black and White students in college calculus than the other blocks of covariates.

Figure 4.5: *Performance Model: Isolated Effects for Each Group of Covariates*

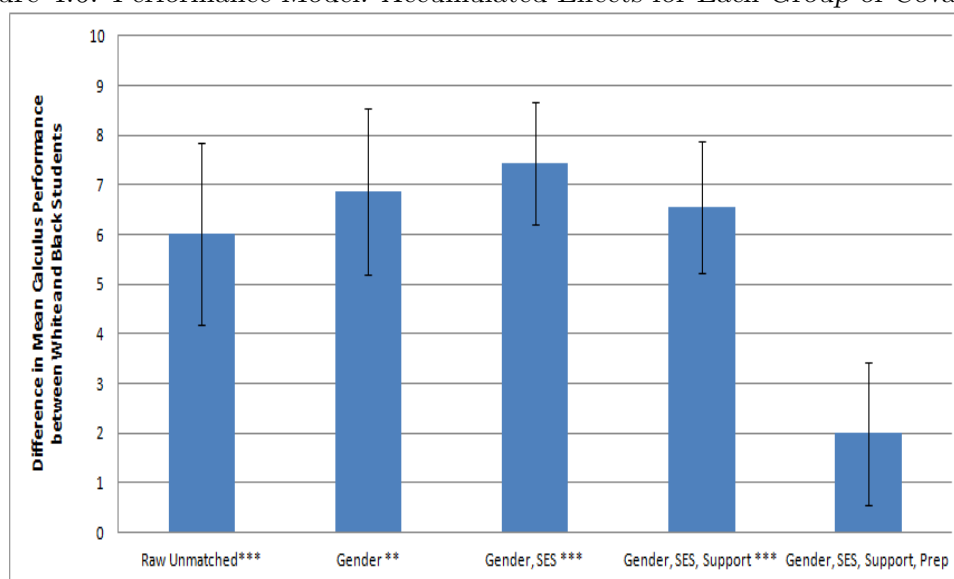


4.5 Accumulated Effects

Since each of the external factors do not affect students in isolated ways, it is important to examine the compounded effect of the covariates. In order to assess the effect of each group of covariates cumulatively, composite models were constructed. The results of these models are illustrated in Figure 4.6. First, the covariate of gender was used to match on, which again led to a 14.5% increase in the difference between White and Black college students' performance in calculus. After adding the SES covariates with gender and achieving balance on these variables, the difference increased by 0.57 of a point leading to an overall difference increase of

1.44 points. So, matching only on the gender and SES covariates led to an overall difference of 7.44 points (Cohen's $d = 0.48$), $p < 0.001$, corresponding to a 24% increase in the performance difference seen between White and Black college students in calculus. Adding the family support covariates along with gender and the SES covariates and achieving balance on these variables, the difference decreased by 0.88 of a point leading to an overall difference increase of 0.56 of a point to a difference of 6.56 points. So, matching only on gender, SES, and family support variables led to an overall difference of 6.56 points (Cohen's $d = 0.42$), $p < 0.001$. This corresponds to a 9.33% increase in the difference between White and Black college students in college calculus performance. Finally, after including the academic preparation covariates, the difference decreased by 4.56 points leading to an overall difference decrease of 4 points. So, matching and achieving balance on all of the gender, SES, family support, and academic preparation covariates led to an overall difference of 2 points, $p = 0.1903$ (Cohen's $d = 0.13$), corresponding to an overall 66.7% decrease in the difference between White and Black college students' calculus performance.

Figure 4.6: *Performance Model: Accumulated Effects for Each Group of Covariates*



Chapter 5

Results: Participation Differences

This chapter will summarize the results of the analyses for the second research question: What, if any, effect do these external factors have on the choice of a STEM career for Black and White college students? Similar to the analyses run for the previous research question, overall and separate models were constructed in order to assess the isolated and collective effect of the groups of covariates on the choice of a STEM career.

A similar approach was taken in the combining of the results of the multiply imputed data as in the previous chapter.

5.1 The Overall Model

For the overall model, each of the 13 variables presented in Chapter 3 were chosen as the covariates desired to match and achieve balance on. Table 5.1 summarizes descriptive statistics for the covariates before and after matching for both groups of students. For each covariate, there were significant differences in the responses between the groups of Black and White students before matching. However,

after one-to-one matching, the groups were balanced with no significant differences on these covariates.

Table 5.1: *Participation Model: Covariate means before and after matching*

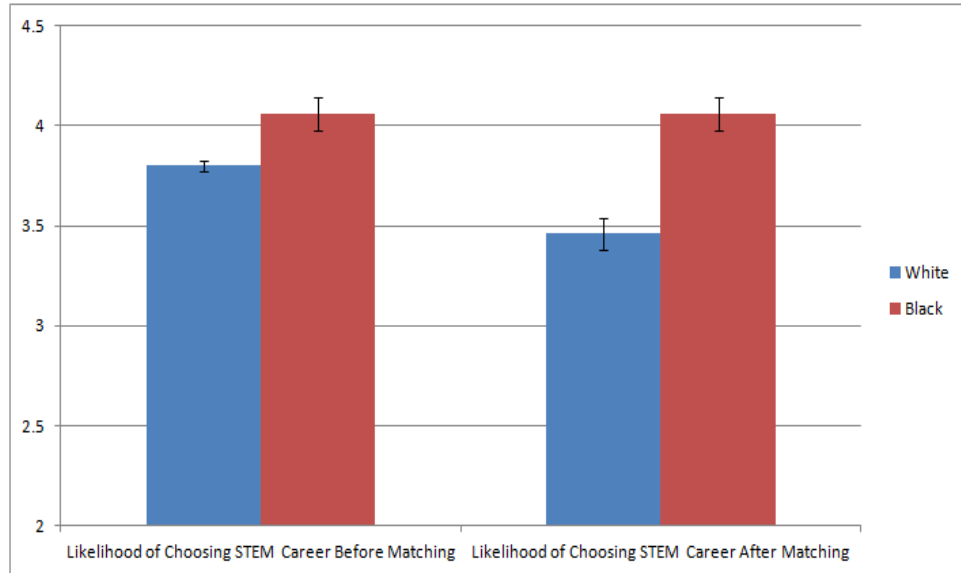
| | Black Mean n=540 | White Mean Before n=4,628, | White Mean After n=540 |
|--|---------------------|-------------------------------|---------------------------|
| Covariates | | | |
| Gender (0=female; 1=male) | 37% | 48%*** | 38% |
| SOCIOECONOMIC STATUS | | | |
| Annual Per Capita In- come | \$19,030 | \$23,070*** | \$19,241 |
| Father's Education Level [†] | 1.77 | 2.30*** | 1.81 |
| Mother's Education Level [†] | 2.00 | 2.27*** | 1.97 |
| FAMILY SUPPORT | | | |
| Home Environment Sup- portive of Science [◇] | 2.56 | 3.06*** | 2.61 |
| Science is a way to a bet- ter career | 18% | 21%* | 17% |
| Science was of no interest to my family | 51% | 37%*** | 51% |
| No one encouraged me to take science classes | 52% | 44%*** | 52% |
| Mother encouraged me to take science classes | 19% | 29%*** | 19% |
| Father encouraged me to take science classes | 11% | 28%*** | 11% |
| ACADEMIC PREPARATION | | | |
| SAT/ACT Math Score | 448 | 523*** | 450 |
| Grade in most advanced math course | 2.93 | 3.12*** | 2.98 |
| Number of HS math courses taken | 3.30 | 3.61*** | 3.31 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; †: 0=Less than high school, 1=High school diploma/GED, 2=Some college/Associate degree,

3=Bachelor's degree, 4=Master's degree or higher; ◇: 0=Not supportive at all; 6=Very supportive

Before any matching, Black students reported a higher likelihood of choosing a career in STEM than the group of White students. On average, Black students rated their likelihood of choosing a career in a STEM field at 4.06 (on a scale from 1-6) while White students rated their likelihood of choosing a career in STEM at 3.8. So the difference between the two groups was 0.26 (Cohen's $d = 0.13$), $p < 0.01$. After matching on all 13 covariates listed in Table 5.1, the difference between the Black and White students increased from 0.26 of a point to 0.6 of a point (Cohen's $d = 0.32$), $p < 0.001$. This is displayed in Figure 5.1.

Figure 5.1: *Difference in Likelihood of Choosing STEM Career Before and After Matching*



This result indicates that when compared to White students with similar backgrounds, the difference in Black and White students' likelihood of choosing a STEM career is increased by 131%. This suggests that despite coming from a more disadvantaged background on average, than White students, Black college students are still significantly more likely to report STEM career aspirations.

5.2 The Isolated Effects

In order to assess the isolated effects for each group of covariates, separate models were constructed. There were a total of four models, one for each group of covariates (including gender), and balance on the specified covariates was achieved for each one. The results of these separate models are presented in the next four subsections and are illustrated in Figure 5.2.

5.2.1 Gender

For the Gender model, only one variable, `q40gender`, was used as the covariate to match and achieve balance on. As stated previously, before any matching there was a .26 of a point difference between Black and White college students in likelihood to choose a career in STEM. After matching solely on gender, the difference increased by 0.08 of a point to a difference of 0.34 of a point (Cohen's $d = 0.17$), $p < .05$. The difference increase could be attributed to the fact that there were significantly more males in the White group of students (48%) than in the Black group of students (37%). Had gender not been used as a covariate to match and achieve balance on, there was a much greater chance of a Black female being matched to a White male. Considering that the difference in the likelihood of choosing a career in STEM between Black males (4.42) and White males (3.86) is higher than the difference between Black females (4.06) and White males, matching on gender causes the Black males to be matched with a White male and therefore increased the difference.

5.2.2 Socioeconomic Status

For the Socioeconomic Status (SES) model, three variables were used as the covariates to match and achieve balance on: `zp_pcapincm`, `q47hpemrecode`, and

`q47hpefrecode`. After matching on only these variables the difference increased by 0.01 of a point to a difference of 0.27 (Cohen's $d = 0.14$), $p < 0.05$. This result of a small increase in difference indicates that the SES variables used, when isolated, do not explain or account for the difference seen in the likelihood of choosing a STEM career between Black and White college students.

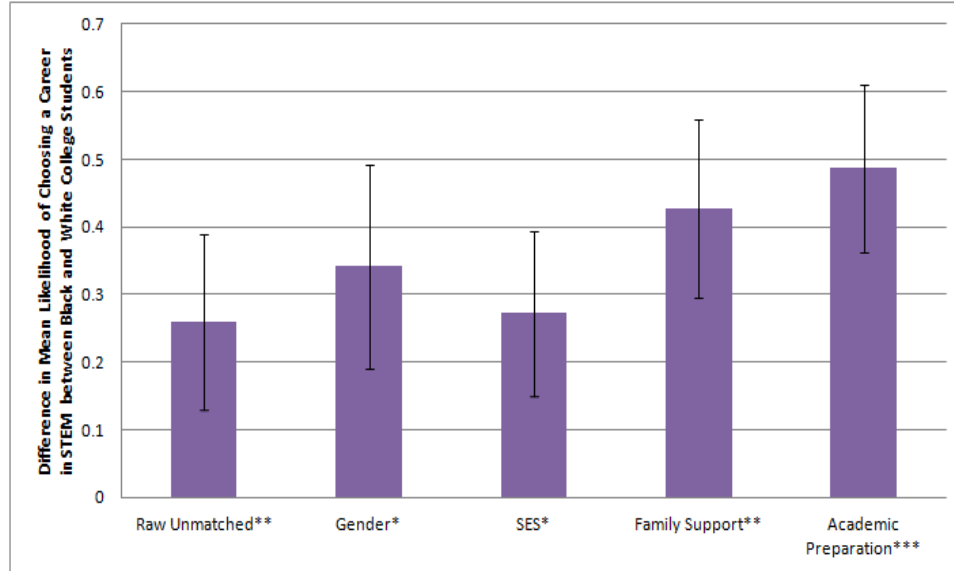
5.2.3 Family Support

For the Family Support model, six variables were used: `q45suprt`, `q46noone`, `q46dad`, `q46mom`, `q49bettr`, and `q49noint`. After matching and achieving balance on only these variables, the difference increased by 0.17 of a point to a difference of 0.43 (Cohen's $d = 0.22$), $p < 0.01$. So, matching only on the family support covariates led to a 68% increase in the difference between Black and White students in likelihood of choosing a career in STEM.

5.2.4 Academic Preparation

For the Academic Preparation model, three variables were used: `q12act_satm`, `q10totlm`, and `q11himg`. After matching and achieving balance on only these variables, the difference increased by 0.23 of a point to a difference of 0.49 (Cohen's $d = 0.26$), $p < 0.001$. Therefore, after isolating the academic preparation variables and achieving balance on them, the difference in the likelihood of choosing a career in STEM between Black and White college students increased by 88%.

Figure 5.2: *Participation Model: Isolated Effects for Each Group of Covariates*

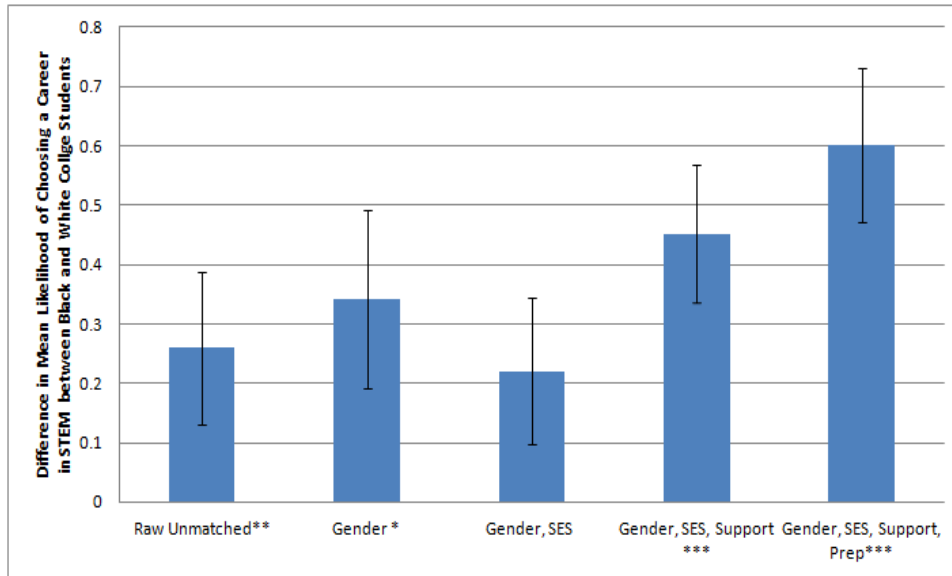


5.3 Accumulated Effects

In order to assess the compounded effect of each group of covariates, cumulative models were constructed. The results of these models are illustrated in Figure 5.3. First, the covariate of gender was used to match on, leading to a 31% increase in the difference-points between Black and White college students' likelihood of choosing a career in STEM. After adding the SES covariates with gender and achieving balance on these variables, the difference decreased by 0.12 of a point leading to an overall difference decrease of .04 points. So, matching only on the gender and SES covariates led to an overall difference of 0.22 (Cohen's $d = 0.12$), $p = 0.1439$, corresponding to a 15.3% decrease in the difference in likelihood of choosing a career in a STEM field between Black and White college students. Adding the family support covariates along with gender and SES covariates and achieving balance on these variables, the difference increased by 0.23 of a point leading to an overall difference increase of 0.19 of a point. Thus, matching only on gender, SES, and family support

covariates led to an overall difference of 0.45 of a point (Cohen's $d = 0.24$), $p < 0.001$, or a 73.1% increase in the difference between Black and White college students' reported likelihood of choosing a career in STEM. Finally, after including the academic preparation covariates, the difference increased by 0.15 of a point leading to an overall increase of 0.34 of a point. So, matching and achieving balance on gender, SES, family support, and academic preparation covariates led to an overall difference of 0.60 (Cohen's $d = 0.32$), $p < 0.001$, corresponding to an overall 131% increase in the difference between Black and White college students' likelihood of choosing a career in a STEM field.

Figure 5.3: *Participation Model: Accumulated Effects for Each Group of Covariates*



Chapter 6

Discussion

The purpose of this study was to compare the differences in calculus performance and likelihood of choosing a career in a STEM field between Black and White college students. However, the goal was to compare representative groups of college students with similar backgrounds with respect to socioeconomic status, family support, and academic preparation. This study complements some of the previous work that has been done on the Black-White gaps seen in mathematics achievement and STEM participation by examining multiple external factors which may work to influence the disparities seen between the two groups. Additionally, this study was able to examine the factors hypothesized to influence mathematics achievement and participation in STEM both in isolation and collectively.

6.1 Understanding the Results: Achievement Differences

6.1.1 Collective Effects on Performance

Before any matching Black students performed significantly worse than White students in their college calculus courses. After matching and achieving balance between the two groups of students on 19 covariates dealing with socioeconomic status, family support, and academic preparation, the difference in calculus performance between the two groups of students reduced to a non-significant gap. This result indicates that when compared to White college students with similar backgrounds, Black college students are performing, on average, about the same in their calculus courses.

The motivation behind using the statistical technique of matching in this study was to compare a nationally representative group of Black university students enrolled in calculus to a group of their White counterparts from similar backgrounds. As stated earlier, one of our nation's biggest concerns is the achievement gap seen when Black students are compared to other students, specifically, their White peers. However, this study, particularly the result from the overall performance model, shows that the blanket claim that Black college students are performing worse than White college students in calculus can be misleading. This statement, while correct when taken at face value, can lead to many generalizations about Blacks and their intelligence or capacity for learning in calculus and other courses. Before matching, the descriptives for the covariates point out that Black students are entering colleges and universities with significantly different backgrounds than their White peers. As a result, when these Black college students are compared to others, it is not always a fair or equitable

comparison. In other words, completely equal and balanced groups are not being compared.

Therefore, when making statements about the underperformance of Black students, it is necessary and helpful to point out some of the underlying factors that may contribute to the differences observed. That is to say, it should be recognized that Black students, on average, do not have the same experiences or come from the same backgrounds as White students. However, for the White students who enter universities with similar experiences and backgrounds as Black students, their performance is not vastly different from these Black students in college calculus. More importantly, this suggests that it is these factors of SES, family support, and academic preparation that are working collectively to influence the underperformance of Black students in college calculus. This claim is based on the evidence that while the isolated and accumulated effects account for some of the difference seen in performance, it was only the overall performance model with all of the covariates collectively that resulted in a non-significant gap.

6.1.2 Isolated/Accumulated Effects on Performance

Although the result from the overall performance model lends to an intriguing claim, it is also useful and beneficial to take a closer look at the results of the isolated and accumulated effects performance models. In actuality, it is these models that help to make clear the areas that may be working to influence the calculus performance gap the most and therefore, the areas that need to be focused on for future work.

It was observed that, as opposed to accounting for a proportion of the performance gap between White and Black college students, matching solely on the socioeconomic status variables actually led to an increase in the difference. Also,

when the SES covariates were added to the performance model with gender, the difference widened. This leads to the claim that when compared to White students with similar community income and parental educational backgrounds, Black students are performing worse than when they are compared to White students with differing backgrounds. From the data used in this study, it is observed that the differences in calculus performance between White and Black college students are higher at the lower income levels and at the parental education levels of high school and less than four years of college. This finding is interesting and a bit surprising. It was found that when 12th grade student performance is broken out by parental education attainment categories (as reported by students), NAEP mathematics score gaps between Whites and Blacks showed different patterns. In 2000, the gap between Whites and Blacks whose parents did not finish high school was 16 points, and the gap between Whites and Blacks whose parents had graduated from college was 35 points. So, at the high school level, the mathematics gaps are larger at higher SES levels than at the lower levels. However, this study reveals that at the college level, the performances differences are higher at the lower SES levels than at the higher levels. This suggests that SES has contrasting effects at the secondary and post-secondary level. From the results, it was also observed that White students at the lower SES levels were actually performing slightly better or the same as White students at the higher levels. Also, while there is an upward trend for Black students across the income levels in performance, there is not a discernible trend for the White students across the income levels. This finding indicates that family income seems to have more of an influence on Black students' performance than on White students' performance. However, there exists an upward trend across mother's education levels for both groups, although no trend is apparent for father's education levels for either group. In other words, as mother's education level increases, so does calculus performance. Therefore, while mother's

education has an affect on both Black and White students' calculus performance, father's education level does not seem to have as much of an effect.

So, while it may seem convenient to point the finger at socioeconomic differences for the achievement gap seen between Black and White students in mathematics, this study shows that attention may need to be focused elsewhere. There has been a long-standing belief that SES has a significant effect on achievement in mathematics education [Grootenboer and Hemmings, 2007]. In fact, literature is consistent in confirming that students who attend low-SES schools achieve significantly lower than students who attend high SES schools. Furthermore, often SES is closely related to racial background [Atweh et al., 2004]. However, when it comes to the Black-White gap in college calculus performance, the SES covariates do not explain any of the observed difference. This is not to say that SES plays no role in influencing the gap, since the resulting increase in difference after matching on only those variables lets us know otherwise. But, the argument that Black students are performing worse than their White peers in college calculus because they come from lower SES families and backgrounds is false.

Matching and achieving balance on the family support variables did account for a small portion of the calculus performance difference between the two groups. However, the difference between White and Black students was still statistically significant. Thus, when Black and White college students with similar family support structures are compared, Black students, on average, are still underperforming in college calculus, but with a smaller effect than when the groups of students are left unmatched. Once the family support covariates were added to the performance model along with the gender and SES variables, the difference decreased from the model with only gender and SES, but increased from the raw unmatched groups. However, the decrease in difference after adding the family support variables suggests that these

covariates still have a meaningful effect on calculus performance.

Therefore, coming from a home environment that is supportive of mathematics and having parents that take an interest in math and encourage their child to take mathematics courses, do play a role in the future success of students in mathematics. In fact, it has been shown that although economic hardship and social discrimination provide difficult obstacles to overcome, parents' behaviors, beliefs, attitudes, goals and lifestyles may work to hinder the effects of coming from a disadvantaged background, thereby fostering academic success in these students [Halle et al., 1997].

Also, even though the majority of the literature on parent's education pertains to the direct positive influence on achievement [Jimerson et al., 1999, Kohn, 1963], the literature also suggests that it influences the beliefs and behaviors of the parent, leading to positive outcomes for children and youth [Davis-Kean, 2005]. For example, it was found that parents of moderate to high income and educational backgrounds held beliefs and expectations that were closer than those of low-income families to the actual performance of their children. Low-income families instead had high expectations and performance beliefs that did not correlate well with their children's actual school performance. So, the parents' abilities to form accurate beliefs and expectations regarding their children's performance are essential in structuring the home and education environment so that they can excel in future endeavors [Alexander et al., 1994].

Interestingly, it was the academic preparation group of covariates which led to the greatest reduction in calculus performance difference between White and Black students. In fact, matching and achieving balance on the academic preparation covariates led to the least significant difference of the four isolated groups of covariates. This result implies that when comparing Black and White students with similar mathematics academic backgrounds, though Black students are still performing worse, the

difference is not as glaring as when the groups of students are unmatched. Also, when the academic preparation covariates were added to the performance model along with gender, SES, and family support variables, the difference, as expected, decreased. In a way, this result only confirms what is already believed to be true. The less mathematics preparation a student has, the worse he or she is expected to perform in college mathematics courses. Nonetheless, this result does send a compelling message that Black college students' lack of mathematics preparation is a primary deterrent to their low achievement in calculus.

In terms of course taking, this study lends support to the findings of other studies which found that in high school, academic course taking is an important structural predictor of students' achievement, especially in mathematics [Gamoran, 1987]. However, studies have also found that prior school performance and family background in terms of SES and support account for most of the Black-White gap in course taking [Kelly, 2009, Kelly, 2004]. Therefore, even though academic preparation has the largest effect on the performance difference between White and Black students in college calculus, other background factors could be working to influence academic preparation itself.

6.2 Understanding the Results: Participation Differences

6.2.1 Collective Effects on Participation

Before any matching, Black students reported being significantly more likely to choose a career in a STEM field than White students in college. After matching and achieving balance on 13 covariates dealing with SES, family support, and academic

preparation, the difference in likelihood of choosing a career in STEM between Black and White college students increased. This result indicates that once compared to White students with similar experiences and backgrounds, Black students are even more likely to report choosing a career in a STEM field.

While it should not be surprising that Black students are more likely to report wanting a STEM career given that Black college freshmen report intending to major in STEM at higher rates than White students [Sasso, 2008], the fact that matching on these background covariates led to an increase in the difference is a bit unexpected. It leads to the thought that there must be some other variables unaccounted for or unobserved that affects Black students' decision to pursue STEM careers at a higher rate even when compared to their White counterparts.

6.2.2 Isolated/Accumulated Effects on Participation

Again, although the result of the overall participation model gives some insight into the participation gap, it is the isolated and accumulated effects that tell a clearer story.

When isolated, matching and achieving balance solely on the socioeconomic covariates, only led to a minuscule increase in the difference between Black and White students. While the difference is still significant at the $\alpha = 0.05$ level, this result indicates that SES is neither accounting for nor explaining the differences seen between Black and White students likelihood of choosing a STEM career. However, after adding the SES covariates to the participation model along with gender, the difference between the two groups of students decreased and the difference became statistically non-significant. This suggests that Black males and White males who come from similar socioeconomic backgrounds (without considering any other back-

ground information) are reporting about the same likelihood, on average, of choosing a career in a STEM field. This same argument can be made for Black females and White females. So, it would seem as though SES is not a major factor in the difference seen between Black and White college students' decision to choose a career in STEM.

However, isolating the family support variables caused the difference to increase. Thus, the White students, who were coming from homes similar to Black students with respect to environments that were supportive of science and science course-taking, reported being significantly less likely to choose a career in a STEM field. This result may suggest that family support is not a major factor in Black students' decision to choose a career in STEM or that having a home environment and family supportive of science is more of a factor for White college students in choosing a career in STEM than it is for Black college students. After adding the family support variables to the participation model with gender and SES, the difference in likelihood of choosing a STEM career between the two groups increased. Considering the difference before adding the family support variables was statistically non-significant, the claim that family support is more of a factor for White students than for Black students in the decision to choose a career in STEM is strengthened. This finding supports previous research which finds one of the contextual factors found to be uniquely relevant to the development of adolescents' career interests is parent support [Turner et al., 2004]. However, it also works to show that this finding may be limited or conversely more important for only certain racial groups.

Furthermore, the difference between Black and White students was also increased by matching solely on the academic preparation covariates. Although the outcome variable is a rating on the likelihood of choosing a career in STEM (specifically, mathematics, engineering/technology, life sciences, or physical sciences), the variables used to match on dealt solely with high school mathematics experiences. So,

the result of the increase in difference between the two groups suggests that White students with comparable SAT math scores, performance in high school math courses, and number of high school mathematics courses taken to Black students, are still significantly less likely to report choosing a career in a STEM field. Moreover, adding the academic preparation variables to the performance model along with the other three groups of covariates caused the difference between the two groups to increase further. Investigations of factors that promote mathematics achievement and interest in math and science careers were precipitated by the recognition that mathematics acts as a “critical filter” affecting entry into a wide range of technical careers [Turner et al., 2004]. Also, it is clear from existing work that the number of mathematics courses taken in high school correlates positively with students’ considerations of science-related careers [Lewis and Connell, 2005]. Since Black students report taking fewer mathematics courses in high school, these findings seem to lend to the explanation of the underrepresentation of Blacks in STEM. However, given that Blacks are desiring a career in a STEM field at higher rates than White students, their lack of mathematics courses does not help to explain this aspect. So, again like the effect of family support, the claim can be made that the academic mathematics background of White students plays a larger role in the decision of choosing a career in a STEM field than for Black students.

6.3 Understanding the Effects for Performance and Participation

Now, taking a look at the whole picture, or the results from both research questions, it is observed that although Black students are performing worse than

White students in their college calculus courses, they are still reporting a higher likelihood of choosing a career in STEM. It is noted that for the covariates used to match on in both the performance and participation models, Black students were reporting entering college with significantly different backgrounds than their White peers. Black students in US colleges and universities are coming from lower socioeconomic backgrounds, less supportive home environments of mathematics and science, and less preparation and support academically in mathematics.

When matching on only SES variables, while the difference in calculus performance increased by about 18%, the difference in likelihood of choosing a career in STEM only increased by about 4%. So, the SES covariates used in this study had a small effect on choice of career in STEM, but a medium effect on calculus performance, although not in the way expected. So, while SES does not account for any of the difference seen between White and Black students in college calculus, it also does not have a meaningful effect on the differences seen between the groups in their likelihood of choosing a career in STEM. It is certainly true that SES is an important factor in understanding race-related issues in mathematics achievement and STEM participation, especially given the disproportionate number of minority group members who are in low-SES groups. However, the results of this study show that for college calculus performance and for college students decision to enter a career in a STEM field, SES does not influence White and Black students in the same way. Therefore, a closer look at the interactions of race and SES or within-group effects and their influences on achievement and participation may yield more discernible results.

When matching on the family support variables, the difference in calculus performance decreased in magnitude while the difference in likelihood of choosing a career in STEM increased. Also, adding the family support variables to the participation model along with gender and SES led to a greater change in difference proportionally

(104% increase) than adding the family support variables to the performance model with gender and SES (11.8% decrease). Therefore, although the argument can be made for family support being a factor for achievement in college calculus, an even stronger argument can be made for it being more of a factor for choosing a career in a STEM field for White college students.

Isolating the academic preparation variables as the covariates used to match on yielded a decrease in the performance difference and an increase in the likelihood of choosing a career in STEM difference. For both models, academic preparation led to larger effects than any of the other three groups of isolated covariates. From the performance model, the claim is made that academic preparation and background in mathematics should be a factor of interest when studying the Black-White gap in college calculus performance. However, for the participation model, it seems that, despite the lack of mathematics preparation, Black students are still desiring a career path in STEM more than White students with similar mathematics backgrounds.

An overall conclusion from this study is that despite coming from disadvantaged backgrounds and even performing worse in gatekeeping calculus courses, Black college students are still interested in pursuing careers in STEM. Despite the fact that Black students do not seem to be as equipped or prepared for what is commonly perceived as a more difficult task requiring a certain level of skill and intelligence, i.e. entering into a STEM field, they continue to have a higher likelihood of choosing a career in STEM. But, why? While this particular study is not able to answer this question, other research may be able to lend some insight into this.

There exists a concept known as “grit”. Grit is defined as “perseverance and passion for long-term goals” [Duckworth et al., 2007]. It is the ability to work strenuously towards challenges, maintain effort and interest over years despite failure, adversity, and plateaus in progress. The gritty individual approaches achievement as

a marathon; his or her advantage is stamina. Whereas disappointment or boredom signals to others that it is time to change trajectory and cut losses, the gritty individual stays the course. So, in the case of Black college students, it could be that they are not necessarily discouraged by perceived barriers such as low performance or lower socioeconomic status. Instead, Black students may view the disadvantages they encounter as hurdles to simply overcome.

The major social theory of educational and social attainment argues that there is a pattern of cross-generational uplift, with gains in parent education and occupational status in one generation having a positive influence on the next generation [Blau and Duncan, 1967]. There is a growing body of research that indicates that this theory helps to explain attainment processes within Black populations even better than it does for Whites [Carter, 1999]. Not only is there a growing diversity in economic status and educational attainment within the Black population, but there is also evidence that social background and aspirations have a substantial influence on college attendance and college persistence [John et al., 2004].

However, regardless of the significant interest Black students may have in STEM, as stated earlier, the path to a career in STEM is riddled with hurdles in the form of certain college courses. One of these is, of course, college calculus. Despite having intentions and desires to enter into STEM, how well a student performs in introductory college calculus serves as a determinant of their future in STEM. Therefore, for those Black students who desire and plan to major in STEM and later have a career in STEM, their underperformance in college calculus is leading to an inability to continue in a STEM field. Consequently, this leads to the underrepresentation of Blacks in STEM.

The next chapter will summarize the study and its implications of the findings. It will also highlight the limitations of this study and future work that should be done

in order to answer some of the questions brought up by the study and ones that were not able to be answered directly from the results.

Chapter 7

Conclusions

This final chapter gives a summary of the findings of the study. Also, a discussion of the implications and limitations of this work will be presented. Finally, suggestions for future research building on this study and others will be discussed.

7.1 Summary of Work

This study set out to explain the achievement gap seen between Black and White students in college calculus and the participation gap between the two groups in STEM fields using external factors that were previously hypothesized and/or shown to be important contributors to the gap. Preliminary results revealed that Black students perform significantly worse than White students in college calculus courses. However, Black college students are significantly more likely to report choosing a career in a STEM field. Using the statistical technique of matching, this study was able to compare similar groups of Black and White college students on background factors dealing with socioeconomic status, family support, and academic preparation. It was found that after comparing Black and White college students with similar

backgrounds on the mentioned covariates, the difference in average final grade in introductory calculus between the two groups decreased to a statistically non-significant difference. It was also found that the group of academic preparation covariates had the largest effect on, and led to the largest reduction of, the performance difference across all the groups of covariates. Additionally, while the family support covariates also led to a decrease in the performance difference between the two groups, gender and SES covariates each yielded an increase in the overall difference.

For the participation in STEM component of the study, it was found that even after comparing Black college students to White college students with similar backgrounds, the difference in likelihood of choosing a career in a STEM field increased with Black students more likely to report choosing a career in STEM. Again, it was found that the academic preparation variables had the largest effect on, and led to the largest increase of, the participation difference across all the groups of covariates. Each of the other groups of covariates also led to an increase in difference between the two groups, however, the SES covariates by themselves produced a non-significant increase and even led to a small decrease in the difference once added with the gender covariate.

So, despite underperforming in college calculus courses, Black students continue to be valiant towards STEM career pursuits. This interest in pursuing a career in STEM is also in spite of Black students entering universities with significantly more disadvantaged backgrounds than White students. For both samples of students in college calculus courses and in college English courses, Black students report arriving at universities with lower SES backgrounds, less supportive home environments in mathematics and science, and also with less preparation in mathematics. The findings of this study indicate that coming from these disadvantaged backgrounds are working to hinder Black students' performance in college calculus, but not from

desiring a STEM career.

Unlike other studies that have examined the Black-White mathematics achievement and participation gap, this study was able to examine a nationally representative group of Black college students who were equivalent to White college students on factors that have been hypothesized to influence achievement and participation in mathematics and STEM. Also, while other studies have only been able to account for a portion of the mathematics achievement gap between Black and White students by using single or isolated factors, this study was able to narrow the performance gap to a non-significant difference by using a collective group of external background factors.

7.2 Implications

There are several implications that can be drawn from the findings of this study. One intriguing finding of this study was the observation that the group of SES covariates, in isolation, were not able to account for any of the differences between Black and White students' calculus performance or their intention to enter into a career in STEM. Therefore, this implies that the blame cannot be placed on SES for the underperformance and underrepresentation of Blacks in mathematics or STEM, at least at the college level. While the case can be made that SES does play a role in the gap depending on the income bracket being examined, since the gap has been observed to be larger at higher levels of SES than at lower levels, the claim cannot be made that "if you control for [SES], all the differences will disappear". Instead, more work is needed in the examining of the different levels of SES and their intersections with race. Furthermore, the effect of SES at different levels of education needs to be further examined.

The results of this study support the expectation that mathematics-specific

family support and involvement will likely affect student outcomes in mathematics courses. This is justified by the calculus performance gap between White and Black students decreasing after matching solely on family support variables as well as when they were added to the accumulated model. So, educators may be able to attain the best results by effectively implementing activities that facilitate parent-child interactions involving mathematics and that encourage the development of mathematics skills. It may also prove beneficial for educators to even just communicate the importance of parental support in mathematics to the parents themselves. Also, parents could possibly promote their children's mastery of mathematics-related skills by helping them to engage in educational activities, for example, encouraging them to take advanced mathematics courses and even signing them up for math/science summer camps. Parents can also foster a home environment supportive of mathematics by showing their children how they use math both in their careers and in their personal lives (e.g., how they use computers to do inventory, how they balance their checkbooks) [Turner et al., 2004]. While these suggestions are likely to promote mathematics achievement in all students, they have potential to be especially beneficial for Black students. Especially since Black students enter college with fewer family support mechanisms as compared to their White counterparts.

What may have been the most important finding from this study was that the academic preparation variables had the largest effect on both the performance and participation gap. The fact that the group of academic preparation variables led to a substantial decrease in the calculus performance gap leaves some room for optimism for educators. Indeed, it is the mathematics preparation that educators and policy makers have the most direct control over. When considering SES particularly, it is out of educators' control to affect change in that domain. Also as discussed earlier, it is certainly possible for educators to attempt to influence parents to be more supportive

of their children's academic lives. However, this factor mainly deals with interactions inside the home and cannot be easily manipulated within schools and classroom. Optimism is also shadowed by the onus that is put on school systems and within the mathematics teachers to place more emphasis on preparing black children for future learning rather than allowing them to fall behind.

It is difficult to make direct claims from this study on the improvements that can be made in adequately preparing students for post-secondary mathematics courses (this is explained more in the next section). However, this study does point towards a need to examine mathematics preparation as the key factor in determining post-secondary mathematics performance. Also, one of the findings from matching covariates in the performance model revealed that Black and White students reported similar ratings for their overall quality of their mathematics teachers. This is despite the fact that Black students report significantly less preparation in the subject of mathematics on the other covariates. Therefore, the quality of mathematics teachers that Black and White students are exposed to may be an area worth investigating.

The importance of teacher quality in the academic success of children has led many to point to differential exposure to qualified teachers as a possible explanation for the Black-White achievement gap. There are a number of characteristics and qualifications that have been found empirically to have large and important effects on student learning. Attributes such as teaching experience and subject matter preparation are important in the short term for student achievement, and may have cumulative effects over time [Corcoran and Evans, 1998]. Repeated exposure to inexperienced or underqualified teachers may eventually yield adverse outcomes considerably larger than those observed in any cross-sectional study.

The central role of teacher quality in educational outcomes has led many researchers and policy analysts to point to differential exposure of White and Black

students to effective teachers as a possible contributor to the Black-White mathematics achievement gap [Ferguson, 1998]. Recent research has shown that teachers are unevenly distributed across districts and schools, with less-qualified teachers disproportionately located in schools with students from predominately low-income families and/or racial/ethnic minorities [Corcoran and Evans, 1998]. For example, Black students are more likely than White students to attend high poverty schools [Berends and Penaloza, 2008] and high poverty schools are more likely to have teachers who are less educated and receive poorer pay than richer schools in the same districts [Rubenstein et al., 2007]. Thus, despite the fact that poorer schools often receive more resource allocations per student than richer schools [Rubenstein et al., 2007], teachers at poorer schools may be ill equipped to use these resources to enhance students' learning. What is less clear, however, is whether changes in Black-White exposure to high quality teachers can explain observed trends in the Black-White mathematics achievement gap. Despite intense interest in raising the quality of teachers, consensus is scant over what teacher attributes and pedagogical practices contribute to the academic and social progress of students. Complicating matters is the likelihood that many important traits in promoting educational outcomes – such as patience, dedication, creativity, and communication – are difficult to measure. In addition, the attributes that assist in learning mathematics for one group may not translate to other groups.

Placing a focus on school characteristics, it has been observed that Black students tend to be concentrated in schools where they make up almost the entire student body [Kozol, 2005a]. Jonathan Kozol [2005] found that in many cities wealthier White families continued to leave the city to settle in suburbs, with minorities comprising most of the families left in the public school system. In fact, schools that were already deeply segregated twenty-five to thirty years ago are no less segregated now,

while thousands of other schools around the country that had been integrated either voluntarily or by force of law have since been rapidly resegregating [Kozol, 2005b]. For instance, in Chicago, by the academic year 2002-2003, 87% of public school enrollment was Black or Hispanic; less than 10% of children in the schools were White. Also, in Washington, D.C., 94% of children were Black or Hispanic; less than 5% were White. Therefore, since Black and White students are not attending the same type of schools, the claim can be made that these students are not receiving equal academic training prior to entering college.

7.3 Limitations

This study works to lay some important groundwork for future research. However, a few limitations should be kept in mind when interpreting the findings from this study. While this work certainly highlights some of the important factors that are working together to affect the Black-White achievement and participation gap, what it is not able to do is explain how these factors are influencing these gaps. In other words, while this study was able to highlight where the problems lie for the underperformance of Black students in college calculus, it is not able to pinpoint mechanisms through which these factors are influencing the gaps.

Also, while academic preparation yields the largest effect for both performance in calculus and participation in STEM, the relationship between academic preparation and career choice is not clear. For instance, in the case of the number of high school mathematics courses taken, it has been reported that Black students who take more mathematics courses in high school tend to be more likely to major in and pursue a career in a STEM field [Griffin, 1990, Maple and Stage, 1991, Thomas, 1984]. These findings provide a strong starting point for unraveling the complex relationship

between Black students' high school course taking patterns and their career considerations. The general tendency of those studying the underrepresentation of Blacks is to interpret the correlation identified in these studies as causes of underrepresentation [Lewis and Connell, 2005]. However, as this study has pointed out, Black students are still reporting being more likely to pursue a STEM career despite their lack of mathematics courses. Therefore, more work needs to be done in focusing on how taking more mathematics courses promotes a student's interest in a STEM career and what other factors might be important in making such decisions for Black students.

The group of SES covariates were made up of three variables for both the performance and participation models. These variables dealt with community income and parent's educational background. These are commonly used measures of SES [Crane, 1996] as previous analyses have used two or more such measures and found sizable independent effects on mathematics scores [Hess et al., 1984]. However there are other measures of SES that were not accounted for in this study. For instance, family structure and household size have also been found to have fairly strong correlations to mathematics scores [White, 1982]. The effects of coming from a single-parent home or a home with numerous siblings were not accounted for in this study.

7.4 Future Work

Future work should focus on examining the factors influencing Black students lack of preparation in mathematics. Specifically, a closer look at the pedagogies and environments experienced by Black students in their secondary, and even prior to secondary, mathematics courses would lend to a better understanding of what may

be contributing to the deficiencies in their mathematics preparation. Also, it may be helpful to examine the overall quality of the schools Black students are attending. For instance, examining the quality of the mathematics teachers of Black students and the resources of the schools Black students are attending may point to factors affecting the preparation of students. While other studies have in fact focused on the qualities of teachers within schools with predominately Black or minority populations, more work should be done in examining these factors together so that the largest effects can be isolated and addressed subsequently.

Also, a closer examination of the factors affecting the higher likelihood of Black students choosing a career in STEM is necessary. Knowledge of how career interest develops and is modified over time is important for educators, particularly given the decline in interest in many STEM fields for domestic students. It would provide insight into the knowledge and experiences that students should be provided in mathematics courses, to reinvigorate interest in STEM fields and promote consideration of STEM careers as a real option.

For the performance aspect, it is noted that the group of students were enrolled in college calculus. Therefore, the results from the study can only be generalized to the population of Black and White college calculus students in the US. It is assumed that the Black students that have made it to college and enrolled in a calculus course are different on some factors than other Black students that did not make into college or who have made it to college and do not enroll in introductory calculus. Thus, examination of students at lower levels of mathematics may also be helpful.

Finally, students in college calculus was a valuable group to study given the course's role as a gatekeeper for advanced STEM courses and STEM careers. However, it can be argued that focusing on interventions at the university level in an attempt to rectify the achievement and participation gaps in mathematics and STEM is only

a remedy for symptoms that stem from a much deeper problem. In other words, college calculus may be too late for intervention because Black students are already disadvantaged at this point. Therefore, recognition of a need to examine schooling practices in mathematics at earlier levels for Black students is most pertinent. In particular, as an initial step, future research should focus on identifying at which schooling level the mathematics achievement gaps for Black and White students begin to appear. Attention should then be placed at this level on the various practices and environments within mathematics classrooms and their effect on achievement. Work such as this may in fact lead to a much better understanding of where the lack of preparation in mathematics of Black students is primarily stemming from.

Appendices

Appendix A Factors Influencing College Success in Mathematics (FICSMath) Survey



Harvard-Smithsonian Center for Astrophysics

Science Education Department



FICSMath:

Factors Influencing College Success in Mathematics

Survey of Students in College Calculus

Researchers at the Harvard-Smithsonian Center for Astrophysics and the Harvard Graduate School of Education are interested in your experiences in learning mathematics. By filling out this questionnaire you will help us find ways to improve mathematics education for future students. Make your best estimate for each item and answer as many questions as possible. Your participation is entirely voluntary. Thank you for your help.

This survey should take no longer than 15-20 minutes to complete.

Your name will NOT be included in our study. After your instructor enters your final grade on the last page, he/she will tear off this sheet before sending us the questionnaire.

Use a No. 2 pencil or blue or black ink pen only.



Student Name (Please print.)

Course Name/Number

Contact:
Gerhard Sonnert, Ph.D.
gsonnert@cfa.harvard.edu



Project FICSMath is funded by the National Science Foundation, grant number NSF 0813702.

1

PLEASE DO NOT MARK IN THIS AREA



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.....

- ☐ Public
 ☐ Private, non-Parochial
 ☐ Private, Parochial
 ☐ All-male
- ☐ Public Charter
 ☐ Vocational
 ☐ Magnet School
 ☐ All-female
- ☐ International Baccalaureate
 ☐ Home Schooled

A 10x5 grid of numbers 0-9. The first column is highlighted with a red arrow pointing to it from the left. The grid contains the following numbers:

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 | 9 |

☐ ≤25
 ☐ 26-75
 ☐ 76-200
 ☐ 201-400
 ☐ 401-600
 ☐ 601-800
 ☐ 801-1000
 ☐ 1001-1200
 ☐ >1200

5. What grade did you get in your last high school English course?

- A+ A A- B+ B B- C+ C C- D+ D D- F

☐ Calculus (Non AP) ☐ AP Calculus AB ☐ AP Calculus BC ☐ Dual Credit

| HS Course Subject | Course Level | | | Last Year Taken in HS | Final Grade | Teacher Gender |
|---------------------|--------------------------|--------------------------|--------------------------|------------------------|---|----------------|
| | Regular | Honors | IB | | | |
| Algebra I | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | M F |
| Geometry | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | (M F) |
| Algebra II | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | M F |
| Integrated Math | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | (M F) |
| Pre-Calc./Trig. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | M F |
| Statistics (Non AP) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | (M F) |
| Calculus (Non AP) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | M F |
| Other: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | (8 9 10 11 12) | A+ A- A- B+ B- B- C+ C- D+ D- F P | (M F) |

| AP Course | AP Exam Score | Year Taken in HS | Final Grade | Teacher Gender |
|---------------|---------------|------------------|-------------------------------------|----------------|
| Calculus AB | 1 2 3 4 5 | 9 10 11 12 | A+ A A- B+ B B- C+ C C- D+ D D- F | M F |
| Calculus BC | 1 2 3 4 5 | 9 10 11 12 | A+ (A A- B+ B B- C+ C) C- D+ D D- F | M F |
| Statistics | 1 2 3 4 5 | 9 10 11 12 | A+ A A- B+ B B- C+ C C- D+ D D- F | M F |
| Physics (any) | 1 2 3 4 5 | 9 10 11 12 | A+ (A A- B+ B B- C+ C) C- D+ D D- F | M F |

9. How long has it been since you completed your most advanced high school mathematics course?

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12. How often did that mathematics course meet for longer than an hour?

☐ Every class ☐ 3 or 4 classes per week ☐ 1 or 2 classes per week ☐ Never

13. What was the length of that mathematics course?

☐ A full year ☐ One semester ☐ Less than a semester

14. In terms of learning the material, that mathematics course required:

Very little memorization of procedures ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ A lot of memorization of procedures
Very little conceptual understanding ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ A lot of conceptual understanding

15. What type of calculator did you use most often in that mathematics course?

☐ A graphing calculator ☐ A non-graphing calculator ☐ No calculators were used

16. In what ways were you allowed to use calculators for your work in that course? Mark all that apply.

☐ For simple calculations (e.g., adding/subtracting, multiplying/dividing) ☐ On exams
☐ To compute numeric values of derivatives/integrals ☐ For homework
☐ To plot graphs of functions ☐ Only after a technique had been practiced heavily using paper and pencil
☐ For trigonometric calculations

17. How often did the following occur throughout that high school mathematics course:

| | Never | Few times a year | Monthly | Weekly | Every Class |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Used graphing calculator | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Used computers for support/instruction | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Given online assignments or homework | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

18. How strongly were the following emphasized in that high school mathematics course:

| | Not emphasized at all | 1 | 2 | 3 | 4 | 5 | Emphasized heavily |
|----------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Functions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Vocabulary | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Precise mathematical definitions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Hands-on activities/labs | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Mathematical proofs | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Memorization of formulas | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Mathematical reasoning | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

19. Concerning class discussions, please indicate how often the following occurred:

| | Never | 1 | 2 | 3 | 4 | 5 | Always |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| You felt comfortable asking questions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Students' questions and comments were valued | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Classroom discussions were useful | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Teacher's answers to questions were valuable | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

CONCERNING YOUR TEXTBOOK, HOMEWORK, AND IN-CLASS ASSIGNMENTS IN YOUR MOST ADVANCED HIGH SCHOOL MATHEMATICS COURSE:

20. How large a role did a textbook play in your high school mathematics course?

Not used much ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ Followed it closely

21. How many minutes did you spend reading the textbook both in class and for homework each day on average?

☐ 0 ☐ 10 ☐ 20 ☐ 30 ☐ 40 ☐ More than 40

22. On average, how many minutes did you spend studying or doing work for math outside of class each day?

☐ 0 ☐ 5 ☐ 10 ☐ 15 ☐ 30 ☐ 45 ☐ 60 ☐ More than 60

23. Indicate the number of problems of each type you had to work on in class:

| | None | One/ Month | One/ Week | Two/ Week | 1-2/ Class | 3-4/ Class | 5-6/ Class | 6+ / Class |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Problems with written explanations | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems with multiple choice/true-false | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems with fill-in the blank | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems with multiple parts | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Word problems | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems that involved estimation | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems requiring graphing by hand | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems requiring graphing by calculator | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Problems that involved proofs | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

24. For problems involving calculation, how often were you required to check whether your numerical answer was reasonable?

Very Rarely | 1 | 2 | 3 | 4 | 5 | 6 | Every Class

CONCERNING YOUR TESTS AND QUIZZES GIVEN IN YOUR MOST ADVANCED HIGH SCHOOL MATHEMATICS COURSE:

25. Which of the following types of questions were typically included on your tests or quizzes? *Mark all that apply.*
Problems that:

- ☐ Required calculations without a calculator
- ☐ Involved data presented in tables
- ☐ Concerned material tested earlier in the course
- ☐ Required memorization of terms or facts
- ☐ Were drawn from homework
- ☐ Required essay responses
- ☐ Required sketching, drawing, or graphing by hand
- ☐ Came from standardized exams
- ☐ Required new insight and creativity

26. Which of the following were typically involved with your tests or quizzes? *Mark all that apply.*

- ☐ The teacher gave study guides or practice exams before a test or quiz
- ☐ The teacher allowed "cheat sheets" during tests or quizzes
- ☐ The teacher allowed students to retake or rework an exam for a grade
- ☐ The teacher gave bonus points or extra credit

CONCERNING THE TEACHER OF YOUR MOST ADVANCED HIGH SCHOOL MATHEMATICS COURSE:

27. How would you rate your high school mathematics teacher on the following characteristics?

| | Low | | | | | High |
|--|-----|---|---|---|---|------|
| Was enthusiastic about mathematics | 1 | 2 | 3 | 4 | 5 | 6 |
| Treated all students with respect | 1 | 2 | 3 | 4 | 5 | 6 |
| Used graphs, tables, and other illustrations | 1 | 2 | 3 | 4 | 5 | 6 |
| Highlighted more than one way of solving a problem | 1 | 2 | 3 | 4 | 5 | 6 |
| Made mathematical errors | 1 | 2 | 3 | 4 | 5 | 6 |
| Explained ideas clearly | 1 | 2 | 3 | 4 | 5 | 6 |

28. How often did disruptive students interfere with your learning in your most advanced high school mathematics class?

- ☐ Rarely
- ☐ Once a week
- ☐ 2-3 times per week
- ☐ Once a class
- ☐ Several times during each class

29. What percent of class time were students focused on learning math?

- ☐ Less than 25%
- ☐ 25-50%
- ☐ 50-75%
- ☐ More than 75%

CONCERNING CLASS TIME AND METHODS IN YOUR MOST ADVANCED HIGH SCHOOL MATHEMATICS COURSE:

30. Regarding class and teacher interaction, please indicate how often the following occurred:

| | Very rarely | Once/Month | Once/Week | 2-3 times/Week | Every class |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| The teacher lectured to the class | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Small group discussion/work was held | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Whole class discussions were held | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Students spent time doing individual work in class | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Classmates taught each other | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| You taught your classmates | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

31. Regarding math connections, please indicate how often the following occurred:

| | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Connected math to your everyday-life | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Connected math to real-life applications | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Connected math to other subject areas | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Examples from everyday world were used | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

32. Regarding problem solving, please indicate how often the following occurred:

| | | | | | |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Teacher solved example problems after presenting new material | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Teacher presented various methods for solving problems | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Students solved problems on board | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

33. Regarding teaching aids, please indicate how often the following occurred:

| | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Manipulation of physical objects | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Use of computer simulations or applets | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Teacher incorporated games and prizes into lessons | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

34. Regarding the use of class time, please indicate how often the following occurred:

| | | | | | |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Tests or quizzes were given | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Class time spent preparing for class-related quizzes/tests | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Time spent going over assigned homework | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Time spent reviewing past lessons | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Class time was spent preparing for standardized math exams | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Spent time correcting your own work | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

| | Very rarely | Once/Month | Once/Week | 2-3 times/Week | Every class |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Students were disrespectful to you | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Students were disrespectful to other students | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Students were disrespectful to the teacher | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| The teacher was disrespectful to me | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| The teacher was disrespectful to other students | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

☐ Never ☐ Once/month ☐ Once/week ☐ 2-3 times/week ☐ 4 or more times/week

37. Did you take a calculus course in COLLEGE prior to this one?

43. Which of the following BEST describes your current career goal? *Mark only ONE choice.*

| Which of the following BEST describes your current career goal? <i>Mark only ONE choice.</i> | Current goal | Current goal | Current goal |
|--|-----------------------|--|-----------------------|
| Medical professional (e.g., doctor, dentist, vet.) | <input type="radio"/> | Engineer | <input type="radio"/> |
| Health professional (e.g., nurse, medical technician) | <input type="radio"/> | Computer scientist, IT | <input type="radio"/> |
| Life scientist (e.g., biologist, medical researcher) | <input type="radio"/> | Mathematician | <input type="radio"/> |
| Earth/Environmental scientist (e.g., geologist, meteorologist) | <input type="radio"/> | Science/Math teacher | <input type="radio"/> |
| Physical Scientist (e.g., chemist, physicist, astronomer) | <input type="radio"/> | Other teacher | <input type="radio"/> |
| | | Social scientist (e.g., psychologist, sociologist) | <input type="radio"/> |
| | | Business person | <input type="radio"/> |
| | | Lawyer | <input type="radio"/> |
| | | English/Language Arts specialist | <input type="radio"/> |
| | | Other non-science related career | <input type="radio"/> |

44. Do you agree or disagree with the following statements?

| Do you agree or disagree with the following statements? | | Agree | | Disagree | |
|---|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| I enjoy learning math. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Math is interesting. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Math makes me nervous. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Math is relevant to real life. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Setbacks do not discourage me. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I can do well on math exams. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I look forward to taking math. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I wish I did not have to take math. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I understand the math I have studied. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| Do the following people see you as a mathematics person? | No, not at all | | | | Yes, very much | |
|--|----------------|---|---|---|----------------|---|
| Yourself | 1 | 2 | 3 | 4 | 5 | 6 |
| Parents/Relatives/Friends | 1 | 2 | 3 | 4 | 5 | 6 |
| Mathematics teacher | 1 | 2 | 3 | 4 | 5 | 6 |

46. Are you male or female?

47. What is your race? (For multi-racial, mark all that apply.)

- ☐ White ☐ Asian ☐ American Indian or Alaskan Native
☐ Black ☐ Pacific Islander ☐ Other: _____

48. Are you of Hispanic origin?

- ☐ Yes ☐ No

49. Was English the primary spoken language in your household?

- ☐ Yes ☐ No

50. What year are you in college?

- ☐ Freshman ☐ Sophomore ☐ Junior ☐ Senior ☐ Graduate Student ☐ Other

51. What is your current type of college enrollment?

- ☐ Full-time ☐ Part-time

52. Was your home environment supportive of math?

Not supportive at all | 1 — 2 — 3 — 4 — 5 — 6 | Very Supportive

53. Who encouraged you to take mathematics classes? Mark all that apply.

- ☐ No One ☐ Sibling(s) ☐ Math Teacher
☐ Mother/Female Guardian ☐ Other Relative ☐ Other Teacher
☐ Father/Male Guardian ☐ School Counselor ☐ Coach

54. What was the highest level of education for your male parent or guardian?

- ☐ Did not finish high school ☐ High school ☐ Some college ☐ Four years of college ☐ Graduate school

55. What was the highest level of education for your female parent or guardian?

- ☐ Did not finish high school ☐ High school ☐ Some college ☐ Four years of college ☐ Graduate school

56. Which category best fits you and your parents' or guardians' background?

| Born in United States | |
|---------------------------|--|
| You | <input type="checkbox"/> Yes <input type="checkbox"/> No |
| Male Parent or Guardian | <input type="checkbox"/> Yes <input type="checkbox"/> No |
| Female Parent or Guardian | <input type="checkbox"/> Yes <input type="checkbox"/> No |

57. Which of the following statements best describes your family's interest in mathematics? Mark all that apply.

- ☐ Math is involved in both parents' jobs. ☐ Math was not an interest of my family.
☐ Math is involved in one parent's job. ☐ My parents were able to help me with math.
☐ Math is a way for you to have a better career. ☐ My parents were willing and able to get me a tutor for math.
☐ Math was a series of courses that I had to pass.

58. For each of the following standardized tests, please indicate the highest score you earned on that test by marking the oval closest to your score.

| SAT Exam | SAT Score | | | | | | | | | | | | | | | | Did not take |
|------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | 200 | 300 | 400 | 500 | 600 | 700 | 800 | | | | | | | | | | |
| Math | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Critical Reading | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Writing | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| ACT Exam | ACT Score | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | Did not take | | | |
|---------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| Math | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| English | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Science Reas. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Reading | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| SAT Subject Test | SAT Subject Test Score | | | | | | | | | | | | | | | | Did not take |
|------------------|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | 200 | 300 | 400 | 500 | 600 | 700 | 800 | | | | | | | | | | |
| Math Level 1 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Math Level 2 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

59. Please DO NOT bother to attempt to solve these problems. We would like to know whether or not your high school teacher(s) spent time teaching how to solve these types of problems in any of your high school mathematics courses.

| | Yes | No | | Yes | No |
|---|--------------------------|--------------------------|--|--------------------------|--------------------------|
| Find all solutions to the equation $2\sin\theta = -1$ on the interval $0 \leq \theta \leq 2\pi$. | <input type="checkbox"/> | <input type="checkbox"/> | Give an epsilon-delta proof for the existence of the limit $\lim_{x \rightarrow 2} (3x - 1)$. | <input type="checkbox"/> | <input type="checkbox"/> |
| Evaluate $\ln(\sqrt[e]{e})$. | <input type="checkbox"/> | <input type="checkbox"/> | True or False? $\tan(hx) = \tanh(x)$ | <input type="checkbox"/> | <input type="checkbox"/> |
| Find $\lim_{x \rightarrow +\infty} \frac{x^3 - 5}{4x^3 + x + 1}$. | <input type="checkbox"/> | <input type="checkbox"/> | Find the Taylor series expansion of $\sin(x^2)$. | <input type="checkbox"/> | <input type="checkbox"/> |
| Find $\lim_{\Delta x \rightarrow 0} \frac{f(x + \Delta x) - f(x)}{\Delta x}$ where $f(x) = x^2 + 4x + 9$. | <input type="checkbox"/> | <input type="checkbox"/> | Given $f(x, y) = x^4 + x^3y - 3x^2y^2 + y^4$, find $\frac{\partial}{\partial x} f(x, y)$ and $\frac{\partial}{\partial y} f(x, y)$. | <input type="checkbox"/> | <input type="checkbox"/> |
| Prove that $g(x) = \begin{cases} 1 & -\infty < x < -1 \\ -x & -1 \leq x < 1 \\ x - 2 & 1 \leq x < +\infty \end{cases}$ is continuous at $x = -1$ and $x = 1$. | <input type="checkbox"/> | <input type="checkbox"/> | Evaluate $\iint_D [xy^2 + x^2y + 3] dy dx$ where D is the region $0 \leq x \leq 1, 2 \leq y \leq 4$. | <input type="checkbox"/> | <input type="checkbox"/> |
| Can the function $y = x^3 - x$ be equal to zero in the interval $0 < x < 1$? Why or why not? | <input type="checkbox"/> | <input type="checkbox"/> | | | |

60. We would like to randomly contact the high school mathematics teachers of some of the students participating in this survey. Without mentioning your name, would it be okay for us to contact the teacher of your *most advanced* high school mathematics course? Remember that your high school teacher will not have any knowledge of your responses to this survey. If yes, please provide the following contact information:

61. **OPTIONAL:** We may want to contact you to ask follow-up questions about your math-related experiences. All communications will be kept in the strictest confidence and your email will NOT be disclosed to any third party.

| FOR PROFESSOR'S USE: | | | | |
|--------------------------|-------------------------------------|--|---|---|
| <input type="radio"/> A+ | <input type="radio"/> D+ | | 0 | 0 |
| <input type="radio"/> A | <input type="radio"/> D | | 1 | 1 |
| <input type="radio"/> A- | <input type="radio"/> D- | | 2 | 2 |
| <input type="radio"/> B+ | <input type="radio"/> F | | 3 | 3 |
| <input type="radio"/> B | <input type="radio"/> Inc. | | 4 | 4 |
| <input type="radio"/> B- | <input type="radio"/> Drop/Withdraw | | 5 | 5 |
| <input type="radio"/> C+ | <input type="radio"/> Pass | | 6 | 6 |
| <input type="radio"/> C | <input type="radio"/> Audit | | 7 | 7 |
| <input type="radio"/> C- | | | 8 | 8 |
| | | | 9 | 9 |

Appendix B Persistence Research in Science and Engineering (PRiSE) Survey



Harvard-Smithsonian Center for Astrophysics

Science Education Department



PRiSE:

Persistence Research in Science & Engineering Survey of Students in Introductory College English

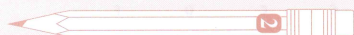
Researchers at the Harvard-Smithsonian Center for Astrophysics are interested in your experiences in learning science. By filling out this questionnaire you will help us find ways to improve science education for future students. Make your best estimate for each item and answer as many questions as possible. Thank you for your help.

**This survey should take between
15 – 25 minutes to complete.**

Confidentiality: Your name and any other identifying information will NOT be included in any reports, published or unpublished, arising from this study. Your anonymity is guaranteed.

Thank you for your time!

Use a No. 2 pencil or blue or black ink pen only.



CORRECT MARK



INCORRECT MARKS



Project PRiSE is funded by the National Science Foundation, grant number NSF 0624444.

1

PLEASE DO NOT MARK IN THIS AREA



15781

ABOUT YOUR CAREER PLAN DEVELOPMENT:

1. Which of the following BEST describes what you want(ed) to be in middle school, high school (beginning and end), and in college? Mark only ONE choice per column.

| | Middle School (Choose one) | Beginning of High School (Choose one) | End of High School (Choose one) | In College (Choose one) |
|--|-------------------------------|---|---------------------------------------|----------------------------|
| Medical professional (e.g., doctor, dentist, vet.) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Health professional (e.g., nursing, pharmacy) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Biologist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Earth/Environmental scientist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Astronomer | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Chemist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Physicist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Engineer | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Computer scientist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other scientist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Mathematician | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Science teacher | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Math teacher | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other teacher | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Social scientist (e.g., psychologist, sociologist) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Business person | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Lawyer | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| English/Language Arts specialist | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other non-science related career | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

2. Rate the following factors in terms of their importance for your future career satisfaction:

| | Not at all important | 1 | 2 | 3 | 4 | 5 | Very important |
|---|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| a. Making money | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| b. Becoming well known | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| c. Helping other people | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| d. Having others working under my supervision | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| e. Having job security | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| f. Working with people rather than objects | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| g. Inventing new things | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| h. Developing new knowledge and skills | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| i. Having lots of family time | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| j. Having lots of time for myself/friends | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| k. Making my own decisions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| l. Having an easy job | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| m. Having an exciting job | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| n. Making use of my talents/abilities | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| o. Working in an area with lots job opportunities | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

ABOUT YOUR MIDDLE SCHOOL SCIENCE EXPERIENCES:

3. What was your average grade in middle school science?

| | | | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A+ | A | A- | B+ | B | B- | C+ | C | C- | D | F |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

4. What was your average grade in middle school math?

| | | | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A+ | A | A- | B+ | B | B- | C+ | C | C- | D | F |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

5. In middle school, how confident were you about your abilities in

| | Not confident at all | 1 | 2 | 3 | 4 | 5 | Extremely confident |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Science | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Mathematics | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

6. In middle school, how interested were you in

| | Not interested at all | 1 | 2 | 3 | 4 | 5 | Extremely interested |
|-------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Science | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Mathematics | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

7. What type of school did you go to? Mark all that apply.

| | | | | |
|----------------------------------|--|--|--|-------------------------------------|
| <input type="checkbox"/> Private | <input type="checkbox"/> Public Charter | <input type="checkbox"/> Magnet School | <input type="checkbox"/> Baccalaureate | <input type="checkbox"/> All-male |
| <input type="checkbox"/> Public | <input type="checkbox"/> Private Religious | <input type="checkbox"/> Vocational | <input type="checkbox"/> Home Schooled | <input type="checkbox"/> All-female |

ABOUT YOUR HIGH SCHOOL BACKGROUND:

8. To help us estimate the size of the community you come from, please provide your home ZIP Code and bubble in the corresponding numbers.

| | | | | |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |
| 2 | 2 | 2 | 2 | 2 |
| 3 | 3 | 3 | 3 | 3 |
| 4 | 4 | 4 | 4 | 4 |
| 5 | 5 | 5 | 5 | 5 |
| 6 | 6 | 6 | 6 | 6 |
| 7 | 7 | 7 | 7 | 7 |
| 8 | 8 | 8 | 8 | 8 |
| 9 | 9 | 9 | 9 | 9 |

9. What grade did you get in your last high school English course?

| | | | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A+ | A | A- | B+ | B | B- | C+ | C | C- | D | F |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

10. Which of the following math courses did you take in high school? *Mark all that apply.*

| | | | | |
|------------------------------------|--|--|---|---|
| <input type="checkbox"/> Algebra I | <input type="checkbox"/> Algebra II | <input type="checkbox"/> Pre-Calculus | <input type="checkbox"/> Calculus | <input type="checkbox"/> AP Calculus BC |
| <input type="checkbox"/> Geometry | <input type="checkbox"/> Integrated Math | <input type="checkbox"/> Trig./Analytic Geometry | <input type="checkbox"/> AP Calculus AB | |

11. For the most advanced math course you took what was your final grade?

| | | | | | | | | | | |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| A+ | A | A- | B+ | B | B- | C+ | C | C- | D | F |
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

12. For each of the following standardized tests, please indicate the score you earned on each subtest by marking the appropriate numbers.

| SAT Score | SAT Exam | | | ACT Score | ACT Exam | | | |
|------------------|-----------------------|-----------------------|--------------------------|-----------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Math Subtest | Writing Subtest | Critical Reading Subtest | | Math Subtest | English Subtest | Science Reasoning | Reading Subtest |
| 200-300 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 1-4 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 310-400 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 5-8 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 410-500 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 9-12 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 510-600 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 13-16 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 610-700 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 17-20 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| 710-800 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 21-24 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 25-28 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 29-32 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | 33-36 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Did not take SAT | Did not take ACT | | | | | | | |

13. For the high school science courses you took in biology, chemistry, and physics, please indicate the level of the course, in what high school year you took the course, what grade you earned, and the gender of the teacher. *Mark only ONE level, year, grade, and gender per row. Leave the row blank if you did not take the corresponding course.*

| HS Course Subject | Course Level | | | | | Year Taken in HS | Final Grade | Teacher Gender |
|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------|-----------------------------|----------------|
| | Regular | Honors | AP | IB | Other Advanced | | | |
| 1 st Biology | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (8 9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| 1 st Chem. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (8 9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| 1 st Physics | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (8 9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| 2 nd Biology | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| 2 nd Chem. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| 2 nd Physics | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |
| Other: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | (9 10 11 12) | A+ A A- B+ B B- C+ C C- D F | (M F) |

14. For each of the AP exams you took, please indicate your test score.

| | AP Test Score | | | | | |
|-------------------------------------|---------------|-----|-----|-----|-----|---|
| AP English Language & Composition | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP English Literature & Composition | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Calculus AB | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Calculus BC | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Biology | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Chemistry | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Physics B | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Physics C Mechanics | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |
| AP Physics C Electromagnetism | (1) | (2) | (3) | (4) | (5) | <input type="radio"/> AP exam not taken |

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PLEASE DO NOT MARK IN THIS AREA

ABOUT YOUR LAST BIOLOGY, CHEMISTRY, AND PHYSICS COURSES IN HIGH SCHOOL:

15. What was required of you to learn the material in your last high school science courses?

| | | | | | | | | |
|------------|--------------------------------------|---|---|---|---|---|---|-----------------------------------|
| Biology: | Very little memorization of facts | 1 | 2 | 3 | 4 | 5 | 6 | A lot of memorization of facts |
| | Very little conceptual understanding | 1 | 2 | 3 | 4 | 5 | 6 | A lot of conceptual understanding |
| Chemistry: | Very little memorization of facts | 1 | 2 | 3 | 4 | 5 | 6 | A lot of memorization of facts |
| | Very little conceptual understanding | 1 | 2 | 3 | 4 | 5 | 6 | A lot of conceptual understanding |
| Physics: | Very little memorization of facts | 1 | 2 | 3 | 4 | 5 | 6 | A lot of memorization of facts |
| | Very little conceptual understanding | 1 | 2 | 3 | 4 | 5 | 6 | A lot of conceptual understanding |

16. How often did a lab directly address a belief or view you had about the world in your last high school science courses?

| | | | | | | |
|------------|-------|---|---|---|---|------------------|
| | Never | | | | | Almost every lab |
| Biology: | 1 | 2 | 3 | 4 | 5 | 6 |
| Chemistry: | 1 | 2 | 3 | 4 | 5 | 6 |
| Physics: | 1 | 2 | 3 | 4 | 5 | 6 |

17. How large a role did a textbook play in your last high school science courses?

| | | | | | | |
|------------|-----------------|---|---|---|---|---------------------|
| | Not used at all | | | | | Followed it closely |
| Biology: | 1 | 2 | 3 | 4 | 5 | 6 |
| Chemistry: | 1 | 2 | 3 | 4 | 5 | 6 |
| Physics: | 1 | 2 | 3 | 4 | 5 | 6 |

18. How many MINUTES, on average, did you spend studying or doing work outside of class each day for your last high school science courses?

| | | | | | | | |
|------------|---|---|----|----|----|----|------------|
| | 0 | 5 | 10 | 15 | 30 | 45 | 60 or more |
| Biology: | | | | | | | |
| Chemistry: | | | | | | | |
| Physics: | | | | | | | |

19. Please indicate how often the following activities or events occurred:

| | | | | | | | | |
|------------|---|------|-------------|------------|-----------------|-----------|----------------|-----------|
| | | None | Very rarely | Once/month | 2-3 times/month | Once/week | 2-3 times/week | Every day |
| Biology: | The teacher lectured to the class | | | | | | | |
| | Spent time doing individual work in class | | | | | | | |
| | Tests or quizzes were given | | | | | | | |
| | You taught your classmates | | | | | | | |
| | Watched science videos | | | | | | | |
| | Went on field trips | | | | | | | |
| | Guest speakers visited your class | | | | | | | |
| Chemistry: | Did hands-on or lab work | | | | | | | |
| | The teacher lectured to the class | | | | | | | |
| | Spent time doing individual work in class | | | | | | | |
| | Tests or quizzes were given | | | | | | | |
| | You taught your classmates | | | | | | | |
| | Watched science videos | | | | | | | |
| | Went on field trips | | | | | | | |
| Physics: | Guest speakers visited your class | | | | | | | |
| | Did hands-on or lab work | | | | | | | |
| | The teacher lectured to the class | | | | | | | |
| | Spent time doing individual work in class | | | | | | | |
| | Tests or quizzes were given | | | | | | | |
| | You taught your classmates | | | | | | | |
| | Watched science videos | | | | | | | |
| | Went on field trips | | | | | | | |
| | Guest speakers visited your class | | | | | | | |
| | Did hands-on or lab work | | | | | | | |

20a. What was the distribution of male and female students in your last high school science courses?

| | | | | | |
|------------|-------------|-------------------------|-------------|-------------------------|-----------|
| | All females | More females than males | About equal | More males than females | All males |
| Biology: | 1 | 2 | 3 | 4 | 5 |
| Chemistry: | 1 | 2 | 3 | 4 | 5 |
| Physics: | 1 | 2 | 3 | 4 | 5 |

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PLEASE DO NOT MARK IN THIS AREA

20b. How frequently were all the members of your group during group or lab work the same sex as you?

| | Never | (1) | (2) | (3) | (4) | (5) | Almost always |
|------------|-------|-----|-----|-----|-----|-----|---------------|
| Biology: | | | | | | | |
| Chemistry: | | | | | | | |
| Physics: | | | | | | | |

21. Please indicate how often the following occurred during your last high school science class:

| | None | Very rarely | Once/month | 2-3 times/month | Once/week | 2-3 times/week | Every class |
|-------------------|--|-------------|------------|-----------------|-----------|----------------|-------------|
| Biology: | Whole class discussions were held | | | | | | |
| | Small group work was held | | | | | | |
| | Connected science to your everyday-life | | | | | | |
| | Connected science to other disciplines | | | | | | |
| | You asked questions | | | | | | |
| | You answered questions or made comments | | | | | | |
| | Other students answered questions or made comments | | | | | | |
| | Students were disrespectful to you | | | | | | |
| Chemistry: | Whole class discussions were held | | | | | | |
| | Small group work was held | | | | | | |
| | Connected science to your everyday-life | | | | | | |
| | Connected science to other disciplines | | | | | | |
| | You asked questions | | | | | | |
| | You answered questions or made comments | | | | | | |
| | Other students answered questions or made comments | | | | | | |
| | Students were disrespectful to you | | | | | | |
| Physics: | Whole class discussions were held | | | | | | |
| | Small group work was held | | | | | | |
| | Connected science to your everyday-life | | | | | | |
| | Connected science to other disciplines | | | | | | |
| | You asked questions | | | | | | |
| | You answered questions or made comments | | | | | | |
| | Other students answered questions or made comments | | | | | | |
| | Students were disrespectful to you | | | | | | |

22. Please indicate whether the following were discussed or occurred in your last high school science class:

| | Biology | Chemistry | Physics |
|--|---------|-----------|---------|
| Science career stages and options | | | |
| Benefits of becoming a scientist | | | |
| Under-representation of women in science | | | |
| Work of female scientists | | | |
| Female scientist guest speakers | | | |
| Currently relevant science topics (e.g., global warming) | | | |
| Ethics related to doing science | | | |
| Teacher's science-related personal experiences/stories | | | |

23. Please indicate the number of problems of each type you had to answer in class and for homework:

| | None | One/week | Two/week | 1-2/Day | 3-4/day | 5-6/day | 6+/day |
|------------------|---------------------------|----------|----------|---------|---------|---------|--------|
| Biology | Problems with: | | | | | | |
| | Long written explanations | | | | | | |
| Chemistry | Long written explanations | | | | | | |
| | Calculations | | | | | | |
| Physics | Long written explanations | | | | | | |
| | Calculations | | | | | | |

24. Please indicate whether the following types of questions were typically included on your science tests or quizzes.

| Problems that: | Biology tests | Chemistry tests | Physics tests |
|--|-----------------------|-----------------------|-----------------------|
| Required calculations | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Could be solved without math | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Drawn from homework | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Involved data analysis | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Required long written responses | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| About material covered on previous tests/quizzes | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Required sketching or drawing | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Required memorizations of terms or facts | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Had multiple-choice/true-false format | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

25. Rate the quality of your last high school science teachers:

| | Poor | | | | | Excellent |
|-------------------|------|-----|-----|-----|-----|-----------|
| Biology Teacher | (1) | (2) | (3) | (4) | (5) | (6) |
| Chemistry Teacher | (1) | (2) | (3) | (4) | (5) | (6) |
| Physics Teacher | (1) | (2) | (3) | (4) | (5) | (6) |

ABOUT YOUR SCIENCE-RELATED INTERESTS/ATTITUDES:

26. When was the earliest experience that you remember learning about or doing science?

- ☐ Pre-K ☐ K-3rd grade ☐ 4-6th grade ☐ 7-8th grade ☐ 9-10th grade ☐ 11-12th grade

27. How do you characterize your earliest experience?

Strongly negative/discouraging — (1) — (2) — (3) — (4) — Strongly positive/encouraging

28. Which of the following applied to your experiences while growing up. Mark all that apply.

- ☐ Tinkered with mechanical devices (e.g., bicycle, car jack, pulleys, wheelbarrow, sewing machine)
☐ Tinkered with electrical devices (e.g., cars, batteries and bulbs, radio, TV)
☐ Watched animal behavior (e.g., bird making a nest)
☐ Observed or studied stars and other astronomical objects
☐ Planted seeds, watched plants grow
☐ Other science-related activity: _____

29. How often did you do the following activities outside of school?

| | Never | Rarely | Few times a year | Monthly | Weekly | Daily |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Participated in science groups/clubs/camps | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Participated in science/math competitions | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Engaged in personal science hobbies | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Read/Watched non-fiction science | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Read/Watched science fiction | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Played computer/video games | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Played sports | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

30. Please rate your general interest in the following:

| HS biology course topics | Not at all interested | | | | | Very interested |
|-------------------------------|-----------------------|-----|-----|-----|-----|-----------------|
| Reproduction & development | (1) | (2) | (3) | (4) | (5) | (6) |
| Evolution | (1) | (2) | (3) | (4) | (5) | (6) |
| Ecology | (1) | (2) | (3) | (4) | (5) | (6) |
| Genetics | (1) | (2) | (3) | (4) | (5) | (6) |
| History & people of biology | (1) | (2) | (3) | (4) | (5) | (6) |
| HS chemistry course topics | Not at all interested | | | | | Very interested |
| Stoichiometry | (1) | (2) | (3) | (4) | (5) | (6) |
| Organic chemistry | (1) | (2) | (3) | (4) | (5) | (6) |
| History & people of chemistry | (1) | (2) | (3) | (4) | (5) | (6) |
| HS physics course topics | Not at all interested | | | | | Very interested |
| Mechanics | (1) | (2) | (3) | (4) | (5) | (6) |
| Optics/Waves | (1) | (2) | (3) | (4) | (5) | (6) |
| Electromagnetism | (1) | (2) | (3) | (4) | (5) | (6) |
| Relativity/Modern Physics | (1) | (2) | (3) | (4) | (5) | (6) |
| History & people of physics | (1) | (2) | (3) | (4) | (5) | (6) |

31. Please rate your general interest in the following areas:

| | Not at all interested | | | | | Very interested |
|---------------------------------------|-----------------------|-----|-----|-----|-----|-----------------|
| Conducting your own experiments | (1) | (2) | (3) | (4) | (5) | (6) |
| Understanding natural phenomena | (1) | (2) | (3) | (4) | (5) | (6) |
| Understanding everyday-life science | (1) | (2) | (3) | (4) | (5) | (6) |
| Explaining things with facts | (1) | (2) | (3) | (4) | (5) | (6) |
| Using mathematics | (1) | (2) | (3) | (4) | (5) | (6) |
| Telling others about science concepts | (1) | (2) | (3) | (4) | (5) | (6) |
| Making scientific observations | (1) | (2) | (3) | (4) | (5) | (6) |
| Wanting to know more science | (1) | (2) | (3) | (4) | (5) | (6) |
| Graduating from college with honors | (1) | (2) | (3) | (4) | (5) | (6) |

32. Compared with other high school courses, please rate the difficulty of the following:

| | Much easier than other courses | | | | | Much harder than other courses |
|--------------------------|--------------------------------|-----|-----|-----|-----|--------------------------------|
| Last HS biology course | (1) | (2) | (3) | (4) | (5) | (6) |
| Last HS chemistry course | (1) | (2) | (3) | (4) | (5) | (6) |
| Last HS physics course | (1) | (2) | (3) | (4) | (5) | (6) |

33. Do the following people see you as a biology/chemistry/physics person?

| | | No, not at all | | | | Yes, very much | |
|------------------|---------------------------|----------------|---|---|---|----------------|---|
| Biology Person | Yourself | 1 | 2 | 3 | 4 | 5 | 6 |
| | Parents/Relatives/Friends | 1 | 2 | 3 | 4 | 5 | 6 |
| | Science teacher | 1 | 2 | 3 | 4 | 5 | 6 |
| Chemistry Person | Yourself | 1 | 2 | 3 | 4 | 5 | 6 |
| | Parents/Relatives/Friends | 1 | 2 | 3 | 4 | 5 | 6 |
| | Science teacher | 1 | 2 | 3 | 4 | 5 | 6 |
| Physics Person | Yourself | 1 | 2 | 3 | 4 | 5 | 6 |
| | Parents/Relatives/Friends | 1 | 2 | 3 | 4 | 5 | 6 |
| | Science teacher | 1 | 2 | 3 | 4 | 5 | 6 |

34. Do you want others to see you as a biology/chemistry/physics person?

| | No, not at all | | | | | Yes, very much |
|------------------|----------------|-----|-----|-----|-----|----------------|
| Biology Person | (1) | (2) | (3) | (4) | (5) | (6) |
| Chemistry Person | (1) | (2) | (3) | (4) | (5) | (6) |
| Physics Person | (1) | (2) | (3) | (4) | (5) | (6) |

35. In your opinion, what is the purpose of science?

| Science: | Not at all important purpose | | | | | Extremely important purpose |
|--|------------------------------|-----|-----|-----|-----|-----------------------------|
| ...helps solve social and practical problems | (1) | (2) | (3) | (4) | (5) | (6) |
| ...helps us understand the basic structure of the world we live in | (1) | (2) | (3) | (4) | (5) | (6) |
| ...provides intellectual excitement | (1) | (2) | (3) | (4) | (5) | (6) |

36. Please indicate which of the following statements best describe you. *Mark all that apply.*

- ☐ I prefer to know just a few people well.
 ☐ I have a wide range of friends and know lots of people.
- ☐ I am seen as "outgoing" or as a "people person."
 ☐ I feel comfortable in groups and like working in them.
- ☐ I am seen as "reflective" or "reserved."
 ☐ I feel comfortable being alone and like things I can do on my own.

37. Please rate your own personality in terms of introversion/extroversion:

Very introverted — (1) — (2) — (3) — (4) — (5) — (6) — Very extroverted

38. If a certain profession was dominated by people of the opposite gender to yourself, how would that influence the likelihood that you would enter that profession?

☐ Strongly decreases likelihood
 ☐ Somewhat decreases likelihood
 ☐ No influence
 ☐ Somewhat increases likelihood
 ☐ Strongly increases likelihood

39. Please rate the likelihood of your choosing a career in:

| | Not at all likely | | | | | Extremely likely |
|------------------------|-------------------|-----|-----|-----|-----|------------------|
| Life sciences | (1) | (2) | (3) | (4) | (5) | (6) |
| Physical sciences | (1) | (2) | (3) | (4) | (5) | (6) |
| Engineering/Technology | (1) | (2) | (3) | (4) | (5) | (6) |
| Mathematics | (1) | (2) | (3) | (4) | (5) | (6) |

ABOUT YOURSELF AND YOUR FAMILY:

40. Are you male or female?

☐ Male ☐ Female

41. What is your race? (For multi-racial, mark all that apply.)

☐ White ☐ Asian ☐ American Indian or Alaskan Native
☐ Black ☐ Pacific Islander ☐ Other: _____

42. Are you of Hispanic origin?

☐ Yes ☐ No

43. Was English the primary spoken language in your household?

☐ Yes ☐ No

44. What year are you in college?

☐ Freshman ☐ Sophomore ☐ Other

45. Was your home environment supportive of science, for example, did you often visit science museums, or zoos?

☐ Not supportive ☐ Occasionally supportive ☐ Moderately supportive ☐ Generally supportive ☐ Very Supportive

46. Who encouraged you to take science classes? Mark all that apply.

☐ No One ☐ Mother/Female Guardian ☐ Father/Male Guardian
☐ Siblings ☐ School Counselor ☐ Science Teacher

47. What was the highest level of education for your parents/guardians?

| | Less than High School Diploma | High School Diploma/GED | Some College/ Associate Degree | Bachelor's Degree | Master's Degree or higher | Not applicable |
|------------------------|-------------------------------|-------------------------|--------------------------------|-----------------------|---------------------------|-----------------------|
| Male parent/guardian | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Female parent/guardian | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

48. Which category best fits you and your parents' or guardians' background?

| | Born in United States | | |
|---------------------------|---------------------------|--------------------------|---------------------------|
| You | <input type="radio"/> Yes | <input type="radio"/> No | |
| Male Parent or Guardian | <input type="radio"/> Yes | <input type="radio"/> No | <input type="radio"/> n/a |
| Female Parent or Guardian | <input type="radio"/> Yes | <input type="radio"/> No | <input type="radio"/> n/a |

49. Which of the following statements best describes your family's interest in science? Mark all that apply.

☐ Science is involved in at least one parent's job. ☐ Science was a diversion or hobby.
☐ Science is a way for you to have a better career. ☐ Science was not a family interest.
☐ Science was a series of courses that I had to pass.

50. OPTIONAL: We may want to contact you to ask follow-up questions about your science-related experiences. All communications will be kept in the strictest confidence and your email will NOT be disclosed to any third party.

Your email address: _____

You have reached the end of the survey.

Thank you very much for your time — it is our goal to have a generation of science educators learn from your insights!



Appendix C R 2.13.0 Code – Final/Separate Models & Matching (FICSMath Data)

C.1 Full Model: Imputed Data Set #1

```
library(Matching)

imputed.psm1 <- read.csv("psm.imp.out.Nov301.csv")
attach(imputed.psm1)

teacherquality <- (q27enthus + q27respect + q27illust + q27alternat
+ V21 + q27clear)/6

#Note: race = V1, HighestMathGrade = V12, NumberOfMathClasses = V16#
Outcome <- q62grade100
Treatment <- V1

X <- cbind(q46gender, zp_medhhncm, q54edfath, q55edmoth, q58act_satm,
q52homesup, q57career, q57noint, q57help, V12, V16, q53none, q53moth,
q53fath, q53couns, q53mathteach, q53othteach, teacherquality,
q50collyear)

BalanceMat <- cbind(q46gender, zp_medhhncm, q54edfath, q55edmoth,
q58act_satm, q52homesup, q57career, q57noint, q57help, V12, V16,
q53none, q53moth, q53fath, q53couns, q53mathteach, q53othteach,
teacherquality, q50collyear)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix =
gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q46gender+zp_medhhncm+q54edfath
+q55edmoth+q58act_satm+q52homesup+q57career+q57noint+q57help+
V12+V16+q53none+q53moth+q53fath+q53couns+q53mathteach+
q53othteach+teacherquality+q50collyear,
data = imputed.psm1, match.out = mgen1, nboots = 1000)
```

```
summary(mgen1)
```

C.2 Isolated Models: Imputed Data Set #1

```
library(Matching)
```

```
imputed.psm1 <- read.csv("psm.imp.out.Nov301.csv")
attach(imputed.psm1)
teacherquality <- (q27enthus + q27respect + q27illust +
q27alternat + V21 + q27clear)/6
```

```
###Trial: Gender###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#
```

```
Outcome <- q62grade100
Treatment <- V1
```

```
X <- cbind(q46gender)
```

```
BalanceMat <- cbind(q46gender)
```

```
set.seed(54321)
```

```
gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)
```

```
mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1, replace = FALSE)
```

```
mb <- MatchBalance(Treatment ~ q46gender, data = imputed.psm1,
match.out = mgen1, nboots = 1000)
```

```
summary(mgen1)
```

```
###Trial: SES###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#
```

```
Outcome <- q62grade100
Treatment <- V1
```

```

X <- cbind(q54edfath,q55edmoth,zp_medhhncm)

BalanceMat <- cbind(q54edfath,q55edmoth,zp_medhhncm)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1,
  replace = FALSE)

mb <- MatchBalance(Treatment ~ q54edfath+q55edmoth+zp_medhhncm,
  data = imputed.psm1, match.out = mgen1, nboots = 1000)

summary(mgen1)

###Trial: Family Support###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#

Outcome <- q62grade100
Treatment <- V1

X <- cbind(q52homesup,q57career,q57noint,q57help,q53none,q53moth,
  q53fath)

BalanceMat <- cbind(q52homesup,q57career,q57noint,q57help,q53none,
  q53moth,q53fath)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1,
  replace = FALSE)

```

```

mb <- MatchBalance(Treatment ~ q52homesup+q57career+q57noint
+q57help+q53none+q53moth+q53fath, data = imputed.psm1,
match.out = mgen1, nboots = 1000)

summary(mgen1)

###Trial: Academic Preparation###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#

Outcome <- q62grade100
Treatment <- V1

X <- cbind(q58act_satm,V12,V16,q53couns,q53mathteach,q53othteach,
teacherquality,q50collyear)

BalanceMat <- cbind(q58act_satm,V12,V16,q53couns,q53mathteach,
q53othteach,teacherquality,q50collyear)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1,replace = FALSE)

mb <- MatchBalance(Treatment ~ q58act_satm+V12+V16+q53couns
+q53mathteach +q53othteach+teacherquality+q50collyear,
data = imputed.psm1, match.out = mgen1, nboots = 1000)

summary(mgen1)

```

C.3 Accumulated Models: Imputed Data Set #1

```

###Trial: Gender and SES###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#

Outcome <- q62grade100

```



```

Treatment <- V1

X <- cbind(q46gender, zp_medhhncm, q54edfath, q55edmoth)

BalanceMat <- cbind(q46gender, zp_medhhncm, q54edfath,
q55edmoth)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q46gender+zp_medhhncm+q54edfath
+q55edmoth, data = imputed.psm1, match.out = mgen1, nboots = 1000)

summary(mgen1)

###Trial: Gender, SES, and Family Support###
#Note: race = V1, HighestMathGrade = V12,
NumberOfMathClasses = V16#

Outcome <- q62grade100
Treatment <- V1

X <- cbind(q46gender, zp_medhhncm, q54edfath, q55edmoth,
q52homesup, q57career, q57noint, q57help, q53none,
q53moth, q53fath)

BalanceMat <- cbind(q46gender, zp_medhhncm, q54edfath,
q55edmoth, q52homesup, q57career, q57noint, q57help,
q53none, q53moth, q53fath)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

```

```
mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q46gender+zp_medhhncm+q54edfath
+q55edmoth +q52homesup+q57career+q57noint+q57help+q53none
+q53moth+q53fath, data = imputed.psm1, match.out = mgen1,
nboots = 1000)

summary(mgen1)
```

Appendix D R 2.13.0 Code – Final/Separate Models & Matching (PRiSE Data)

D.1 Full Model: Imputed Data Set #1

```
library(Matching)

imputed.psm1 <- read.csv("PRiSEBlackWhiteImputed1.csv")
attach(imputed.psm1)

STEM_proxy <- pmax(q39lifsi,q39physi,q39eng,q39math)

#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q40gender,zp_pcapincm,q47hpemrecode,q47hpefrecode,
q45suprt,q46noone,q46dad,q46mom,q49bettr,q49noint,q12act_satm,
q10totlm,q11himg)

BalanceMat <- cbind(q40gender,zp_pcapincm,q47hpemrecode,
q47hpefrecode,q45suprt,q46noone,q46dad,q46mom,q49bettr,
q49noint,q12act_satm,q10totlm,q11himg)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q40gender+zp_pcapincm
+q47hpemrecode +q47hpefrecode+q45suprt+q46noone
+q46dad+q46mom+q49bettr+q49noint +q12act_satm
+q10totlm+q11himg, data = imputed.psm1,
match.out = mgen1, nboots = 1000)

summary(mgen1)
```

D.2 Isolated Models: Imputed Data Set #1

```
library(Matching)

imputed.psm1 <- read.csv("PRiSEBlackWhiteImputed1.csv")
attach(imputed.psm1)

STEM_proxy <- pmax(q39lifsi,q39physi,q39eng,q39math)

###Trial: Gender###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q40gender)

BalanceMat <- cbind(q40gender)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q40gender, data = imputed.psm1,
  match.out = mgen1, nboots = 1000)

summary(mgen1)

###Trial: SES###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q47hpemrecode,q47hpefrecode,zp_pcapincm)

BalanceMat <- cbind(q47hpemrecode,q47hpefrecode,zp_pcapincm)

set.seed(54321)
```

```

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q47hpemrecode+q47hpefrecode
+zp_pcapincm, data = imputed.psm1, match.out = mgen1,
nboots = 1000)

summary(mgen1)

###Trial: Family Support###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q45suprt,q46noone,q46dad,q46mom,q49bettr,q49noint)

BalanceMat <- cbind(q45suprt,q46noone,q46dad,q46mom,q49bettr,
q49noint)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q45suprt+q46noone+q46dad+q46mom
+q49bettr +q49noint, data = imputed.psm1, match.out = mgen1,
nboots = 1000)

summary(mgen1)

###Trial: Academic Preparation###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

```

```

X <- cbind(q12act_satm,q10totlm,q11himg)

BalanceMat <- cbind(q12act_satm,q10totlm,q11himg)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q12act_satm+q10totlm+q11himg,
  data = imputed.psm1, match.out = mgen1, nboots = 1000)

summary(mgen1)

```

D.3 Accumulated Models: Imputed Data Set #1

```

###Trial: Gender and SES###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q40gender,zp_pcapincm,q47hpemrecode,q47hpefrecode)

BalanceMat <- cbind(q40gender,zp_pcapincm,q47hpemrecode
,q47hpefrecode)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
  estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
  M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
  = gen1, replace = FALSE)

mb <- MatchBalance(Treatment ~ q40gender+zp_pcapincm+q47hpemrecode
+q47hpefrecode, data = imputed.psm1, match.out = mgen1,

```

```

nboots = 1000)

summary(mgen1)

###Trial: Gender, SES, and Family Support###
#Note: race = V1#
Outcome <- STEM_proxy
Treatment <- V1

X <- cbind(q40gender,zp_pcapincm,q47hpemrecode,q47hpefrecode,
q45suprt,q46noone,q46dad,q46mom,q49bettr,q49noint)

BalanceMat <- cbind(q40gender,zp_pcapincm,q47hpemrecode,
q47hpefrecode,q45suprt,q46noone,q46dad,q46mom,q49bettr,
q49noint)

set.seed(54321)

gen1 <- GenMatch(Tr = Treatment, X = X, BalanceMatrix = BalanceMat,
estimand = "ATT", pop.size = 1000, data.type.int = FALSE, print = 1,
M = 1, replace = FALSE)

mgen1 <- Match(Y = Outcome, Tr = Treatment, X = X, Weight.matrix
= gen1,replace = FALSE)

mb <- MatchBalance(Treatment ~ q40gender+zp_pcapincm+q47hpemrecode+
q47hpefrecode+q45suprt+q46noone+q46dad+q46mom+q49bettr+q49noint,
data = imputed.psm1, match.out = mgen1, nboots = 1000)

summary(mgen1)

```

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